Comparative effectiveness of individual and group practical investigations in developing integrated science inquiry skills

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March 2015

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DEGREE AND PROJECT	MEd Comparative effectiveness of individual and group practical investigations in developing integrated science inquiry skills
INVESTIGATOR(S)	Hlupheka Edward Baloyi
DEPARTMENT	Science, Mathematics and Technology Education
DATE CONSIDERED	28 November 2014
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DEDICATION

This dissertation is proudly dedicated to all my family members, especially mhani Sarah and my late father, Nthangeni Phineus Mulibana.

ACKNOWLEDGEMENTS

It would never have been easy to accomplish this dissertation without the support and guidance of all people around me and the Almighty God. A number of kind people played critical roles in the success of this dissertation, some of whom it is possible to give particular mention here.

First of all, I would like to thank my supervisor Dr. M.M.M. Kazeni for her excellent guidance, patience and encouragement all the times. This dissertation would not have materialised without her sacrifice. The good advice and support by co-supervisor, Dr. E. Gaigher, has been invaluable academically.

I am most grateful to Abigail Baloyi for always providing unequivocal personal and emotional support, and Nhlayiso and Ntsakisi Baloyi for been patient throughout my studies.

My greatest appreciation is for Hlulani Clayton Sithole and Ian Baloyi, who spent several nights working out on data analysis. Special thanks go to sesi Florence Baloyi, Grace Chauke and Basani Chuma-Mashau for logistical and technical support during data collection at the research sites. My sincere gratitude goes to my friend and study mate Mosibudi Christelda Makhubela for her support and constant motivation during difficult times of the research. To Owen Miyelani Maswanganyi and Tshimangadzo M. Ravele I am humbled by your support in crossing the ts of this dissertation. Elizabeth Stewart, I thank you for your job well done in checking errors and inadequacies. This work would not have been possible without their help.

Last, but by no means least, I thank the Almighty Lord for giving me courage and strength during this study.

ABSTRACT

Practical investigations are an essential part of formal assessment in Physical Sciences in the South African Curriculum and Assessment Policy Statement (CAPS). In rural schools, individual and group works are frequently used in practical investigations. However, it is not clear from existing literature which of the two methods is more effective in enhancing learners' development of Integrated Science Inquiry Skills (ISIS). The purpose of this study was to compare the effectiveness of individual and group practical investigations in the development of ISIS. The research involved 319 purposively selected grade eleven Physical Sciences learners in an educational district in Limpopo Province, South Africa. A mixed-method research approach, primarily involving an experimental comparative design was used to collect quantitative data. Two groups of learners were exposed to either individual or group practical investigations. Pre and post-tests were used to assess learner performance in ISPS. A comparison of the post-test mean performances of the two groups of learners showed no significant difference in their competence in ISPS. The qualitative findings complemented the quantitative data. The implication of the study findings is that, the two teaching approaches used had the same effect on learners' development of ISIS.

Key words: Integrated, inquiry, science, skills, individual, group, investigations, practical, development, constructivism.

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CHAPTER ONE

INTRODUCTION

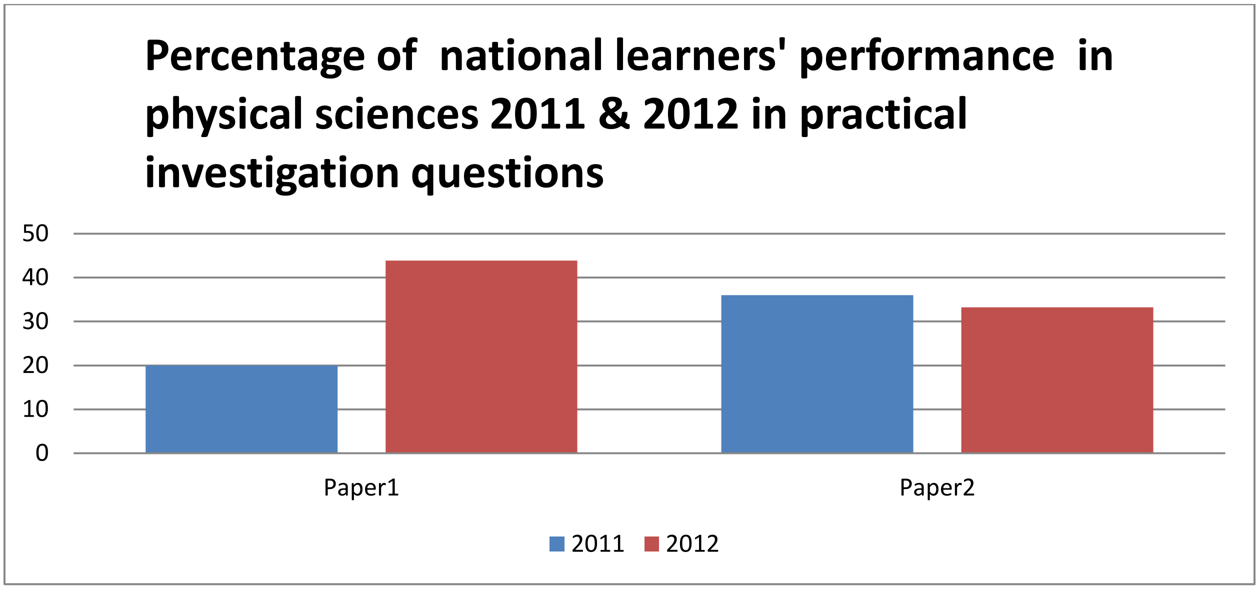
1.1 BACKGROUND TO THE STUDY

Practical investigation tasks are important components of continuous assessment (CASS) in the Further Education and Training (FET) band in physical sciences in the South African basic education system. In South Africa, the Department of Basic Education's (DBE) Curriculum and Assessment Policy Statement (CAPS) Grades 10–12 of the National Curriculum Statement (NCS) prescribes that practical investigations should form part of informal and formal tasks in research projects. Physical sciences CAPS for Grades 10–12 stipulates that investigations and experiments must concentrate on practical features, including the development of science inquiry skills and problem-solving skills. Consequently, formal controlled tests and examinations assess learner performance on science inquiry skills at different cognitive levels (DBE, 2011).

Many science curriculum guides and instructional materials – such as the CAPS physical sciences document, national examination guidelines, physical sciences pacesetters and national diagnostic reports – emphasize the development of science inquiry skills (Kazeni, 2005:3). Learners utilising these science curriculum documents are anticipated to develop science inquiry skills, such as formulating hypothesis, identifying, controlling and manipulating variables, operationally defining variables, designing and conducting experiments, collecting and interpreting data, and solving problems, in addition to mastering the content of the subject matter (Kazeni, 2005). The development of these skills is important in achieving the goals of CAPS.

The development of science inquiry skills occurs while conducting scientific practical tasks. In spite of the emphasis on the development of these skills by the NCS, the 2011 and 2012 National Diagnostic Reports on Learner Performance in Physical Sciences Grade 12 revealed that learners performed poorly in science inquiry skills assessment. In the 2011 and 2012 examinations, in practical investigation questions, learners' scored 20.0% (question 9) and 43.9% (question 11). Similarly, in paper 2, learner performances were 36.0% (question 6) and 33.2% (question 6), respectively (DBE, 2011 and 2012), as shown in figure 1.1 below.

Figure 1.1 Comparison of national learners' performances in physical sciences in practical investigation questions in the 2011 and 2012 examinations



Source: DBE, 2011 and 2012 National Diagnostic Reports on Learners Performance, Appendix J (figures 1, 2)

The poor performance of learners (figure 1.1) is attributed to lack of practical science experiments in which learners are assumed to acquire science inquiry skills (DBE, 2012:166). For learners to succeed in summative examinations and formal common tests and experiments, they need to perform well in practical investigation tasks during their academic year and develop integrated science inquiry skills. The DBE diagnostic report (2012:188) endorsed this statement and recommended that:

a) Practical investigations should be performed on a regular basis and emphasis should be placed on the investigative question, the hypothesis, variables, method, results, interpretation of results and the conclusion.
b) Candidates should be taught that a conclusion must be stated as a relationship, found experimentally or from given results, between the independent and the dependent variables. More practice is needed to ensure that candidates are familiar with formulating investigative questions, hypotheses and conclusions. In all three cases, the dependent and independent variables should first be identified and then a relationship between these two variables should be identified.

These recommendations place more emphasis on understanding and developing science inquiry skills. Learners' acquisition of scientific concepts is brought about in an effective teaching and learning environment through minds-on and hands-on activities (Balce, 2010). These activities help learners develop the science inquiry skills that enhance understanding of concepts and content of science subjects. Science inquiry skills transcend the content of every science syllabus; hence their development is considered more important than the acquisition of knowledge (Yandila & Komane, 2004). The acquisition of science process skills such as stating hypothesis, analysis, testing hypothesis, carrying out experimental procedures, problem solving, etc. (Yandila & Komane , 2004: 334) is vital because these skills are necessary for effective citizenry in the 21 century. With the explosion of information, learners need these skills to access, analysis and use the relevant content to solve everyday problems. Without these process skills, learners are unlikely to attain relevant content from the available massive body of content knowledge. Science process skills are divided into basic and integrated skills. In this study, the development of certain integrated science inquiry skills was explored, namely identifying and controlling variables, stating hypotheses, giving operational definitions, graphing and interpreting data, and presenting experimental design through practical investigation.

Various teaching methods are applied when teaching practical skills. These include demonstrations, individual practical work, group practical work, computer-simulated experiments, and rational experiments (weekly alternating performance of experiments by each learner (Feyzioglu, 2009:115). The development of science inquiry skills by learners during a science practical lesson depends largely on the kinds of teaching and learning methods that are used. From my experience and observations as a natural science subject advisor and educator, it appears that in most disadvantaged rural secondary schools in South Africa, the two methods that are mostly used for hands-on practical activities are individual practical work and group practical work.

In this study, individual practical investigation in a teaching and learning environment means an individual learner performing a practical activity alone, with the educator acting as a facilitator and resource person. The individual learner uses the information gained from his or her own learning experiences, the educator and the surrounding natural environment to define the natural world. In individual practical tasks, the learner studies the task and uses science inquiry skills to provide a solution without assistance from social structures, for example the learner group or class.

'Group work' is a term associated with cooperation and collaboration (Christensen & McRobbie, 1994). 'Cooperation' may simply mean working together as group to achieve a particular goal, while 'collaboration' means working together, including sharing ideas. Constantopoulos (1994:251) defines cooperative learning as 'a concept based on group work in which learners are responsible for others as well as their own learning'. Both terms are appropriate in this study and will be used interchangeably. Rapudi (2004) indicated that there are many methods of cooperative learning including the ‘group investigation method’ initiated by Sharan and Hertz-Lazarowitz in 1980. In the group investigation method, learners plan cooperatively and conduct their investigations, and the educator serves as a facilitator and resource person. The main goals of cooperative learning methods are to facilitate positive social relations and increase academic achievement in the heterogeneous classroom (Rapudi, 2004).

Educators use individual work and group work interchangeably or use only one method when teaching practical activities. Consequently, it is not clear from the literature which of the two approaches in teaching practical investigations is more effective in enhancing learners’ development of integrated science inquiry skills. An evaluation of the literature indicates that there is a few research documents based on learners’ development of integrated science inquiry skills in South Africa, in the FET band (Rambuda & Fraser, 2004; Rapudi, 2004; Dlamini, 2008). It is against this background that this study seeks to find out which learning method, namely individual practical investigation or group practical investigation, significantly enhances learners’ development of integrated science inquiry skills during practical investigation tasks, in an attempt to find ways of improving their achievement in science inquiry skills assessment in informal and formal tests and summative examinations. In this study, the phrases “individual treatment learners and group treatment learners” will be used to represent learners exposed to individual practical investigations and group practical investigations respectively.

1.2 PROBLEM STATEMENT

The subject assessment guideline for physical sciences Grades 10-12 stipulates that learners must be taught scientific inquiry tasks (DoE, 2008). These tasks are in a form of practical investigations that involve the development of science inquiry skills, especially integrated science inquiry skills. These practical investigation tasks are performed as common assessment tasks. As a physical sciences subject advisor, the researcher has noted that in the district moderation of the common assessment tasks of practical investigation, learners do not perform well. Previous examination results for Grade 12 show that learners are not doing well on questions dealing with science inquiry skills. According to the November 2012 Physical Sciences Examination Report (DBE, 2012) and other previous examinations (2011), candidates performed poorly on questions based on practical investigation set pieces. These are based on integrated science inquiry skills.

Learners' poor performance on questions based on integrated science inquiry skills indicates that they have difficulty in responding to such questions. This poor performance is seen against the background that the CASS mark contains 40 per cent practical investigation tasks based on integrated science inquiry skills developed during the academic year. Educators are required to teach integrated science inquiry skills during practical investigation tasks to enable learners to develop scientific inquiry skills. This accommodates CASS mark requirements and prepares learners to answer questions based on integrated science inquiry skills during controlled common tests and examinations, that is, formative and summative tasks, respectively. For a learner to respond well to questions involving science inquiry skills there should be clear development of these skills. As stated earlier, the development of integrated science inquiry skills can be achieved in various ways in the teaching-learning environment. The instructional methods for developing integrated science inquiry skills and enhancing their understanding by learners vary, and include individual and group work learning.

Problems associated with the teaching of scientific investigation include lack of teacher preparation, lack of resources, pressure to cover content, focus on examinations, and teaching methodology (Dlamini, 2008). In terms of teaching methodology, Dlamini indicated that educators rely on traditional methods when teaching experimentation. These include lectures, demonstrations, and group work. However, a review of literature shows that most educators are not competent to teach practical investigations using group work. For instance, Ajaja and Eravwoke (2010) reported that most educators are not sensitised to the advantages of the use of cooperative learning. In consequence, at times educators use group work citing insufficient resources for individual practical work (SCORE, 2008). Given that both individual and group investigations are commonly used in science classrooms, the question is: Which learning method between individual practical investigation and group practical investigation enhances the development of integrated science inquiry skills during a science lesson on practical investigation task? This study seeks to compare the relative effectiveness of individual and group practical investigation learning in enhancing learners' development of integrated science inquiry skills during practical investigation tasks.

1.3 PURPOSE OF THE STUDY

The purpose of this research study was to compare the relative effectiveness of individual practical investigation and group practical investigation learning in enhancing learners' development of integrated science inquiry skills during practical investigation tasks in the Grade 11 physical sciences. Learners were assessed in five integrated science inquiry skills: i) identifying and controlling variables, ii) stating hypotheses, iii) operational definitions, iv) graphing and interpreting data, and v) experimental design.

1.4 RESEARCH QUESTIONS

The primary research question is, How do group practical investigations compare with individual practical investigations in learners' development of integrated science inquiry skills?

Investigative questions

1. Is there any difference in the integrated science inquiry skills developed by learners exposed to individual and those exposed to group (cooperative) practical investigations?
2. How can the development of these science inquiry skills by learners exposed to the two practical investigation learning methods be explained?

The null hypothesis for this investigation was:
There is no significant difference in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations.

The null hypothesis can be expressed as:
H_0: $\mu_{\text{individual treatment performance}} = \mu_{\text{group treatment performance}}$ (where μ = mean/average)

The first investigative question was addressed using quantitative data collection methods, while the second was addressed with qualitative exploration.

1.5 SIGNIFICANCE FOR THE STUDY

In South Africa's FET band, learners are expected to develop scientific inquiry skills, including scientific practical investigation skills. The Grade 12 final examination reports for 2011 and 2012 in physical sciences showed that learners' performance in the theoretical practical investigation questions was very poor. As a curriculum advisor, the researcher found the same trend in Grades 10 and 11 in life and physical sciences subjects. According to the subject assessment guidelines

(DoE, 2008), questions based on theoretical practical investigation require conceptual knowledge gained through science inquiry skills. For learners to perform well in the theoretical investigative tasks and examination, they must acquire knowledge on the concepts involved in practical investigations and develop integrated science inquiry skills. The significance of this study therefore is that it can form a basis for natural science educators to focus on the more effective teaching method between individual work and group work when teaching integrated science inquiry skills using practical investigations. This is particularly relevant in rural areas, where the investigation was conducted, which are characterised by lack of resources, inexperienced and unqualified educators. This study is likely to enable natural sciences educators in rural areas to use an approach to practical investigations which is accessible, convenient and effective in developing learners' investigative skills and concepts. Science inquiry skills incorporate solving problems and understanding scientific concepts. Competence in those skills can enhance learners' abilities in these cognitive areas (Stott, 2005).

Minner, Levy and Century (2010) found significant outcomes on science inquiry teaching methods successes and other educationally important factors. The significant achievement was attributed to the development of science inquiry skills. It is therefore hoped that the results of the study would inform the instructional method that natural sciences educators emphasise during teaching and learning in practical investigation tasks for improved learner performance.

1.6 SCOPE OF THE STUDY

The study focused on teaching and learning models that could improve the development of integrated science inquiry skills when learners conduct science practical activities. The study was conducted in four secondary schools in Mopani education district in Limpopo, South Africa. Participants were Grade 11 (FET band) learners who were taking physical sciences and doing practical investigation tasks in individual or group form. The findings of this study could be applied to similar settings in various science subjects when dealing with the development of science inquiry skills.

The study explored the performance of learners who were exposed to practical investigations as individuals or in groups, in integrated science process skills (ISPS).

1.7 MAIN ASSUMPTIONS

In this study, it was assumed that teaching and learning are interactive processes and occur synchronously. It was also assumed that the teaching method used in the immediate teaching-learning environment determines the subsequent learning method and thus teaching method and learning method were used interchangeably.

In their study Ketelhut, Nelson, Clarke & Dede (2010:57) indicated that some scientists refer to inquiry skills as a set of process skills, which include questioning, hypothesising and testing, while others equate inquiry skills with ‘hands-on’ learning. Previously, Germann, Aram, Odom & Burke (1996b:193) indicated that integrated science inquiry skills “serve as scaffolding for formulating hypotheses, experimenting and evaluating evidence” which are the core practices of scientific inquiry. Following this contention, in this study the phrase ‘science inquiry skills’ is assumed to refer to the ‘science processes skills’ developed by learners when they conduct practical investigations. The phrases ‘science inquiry skills’ and ‘science process skills’ are therefore used interchangeably and hence ISPS is used for integrated science process (inquiry) skills in this study.

1.8 OUTLINE OF THE STUDY

The research study report is outlined as follows:

Chapter 1: Introduction

This section contains the introduction and background of the study.

Chapter 2: Literature review

This chapter focuses on the review of related work by other researchers, and a description of the conceptual framework of the study. It covers learning investigative skills through practical investigations, the importance of science inquiry skills in science teaching, development of science inquiry skills during practical investigations, assessment of integrated science inquiry skills, related studies and the conceptual framework of the study.

Chapter 3: Research methodology

In this chapter, the focus is on research methodology. It contains the research method and design, study variables, sampling procedure and participants, instrumentation, pilot study, main study and ethical considerations.

Chapter 4: Study results

This chapter deals with presentation of data collected from empirical investigations of the main study. Results presentation is based on both quantitative and qualitative data.

Chapter 5: Discussion of results

The analysis and interpretation of the results is done in this chapter, where the results of the study are discussed in detail.

Chapter 6: Summary and conclusion

This chapter focuses on summary of results and recommendations. Other components include implication of results in education, limitation of this study and sections for consideration for additional research.

The following chapter deals with a review of related literature.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The teaching of science inquiry skills plays an important role in learners' understanding the scientific way of performing practical investigation tasks in science education. Learners would be able to develop integrated science inquiry skills successfully if they were exposed to effective teaching-learning methods when performing practical investigations. This section deals with a review of literature on learning investigative skills through practical investigations, the importance of science inquiry skills in science teaching, the development of science inquiry skills during practical investigations, and assessment of integrated science inquiry skills. Other studies related to this research and the conceptual framework of the study are discussed.

2.2 LEARNING INVESTIGATIVE SKILLS THROUGH PRACTICAL INVESTIGATIONS

Practical work is a distinctive feature of science education (Millar, 2009). It is a minds-on and hands-on experience that prompts scientific thinking about the world in which we live. Practical work involves two types of activities, namely scientific techniques and procedures (in the laboratory and in the field), and scientific enquiries and investigations (SCORE, 2008). The significance of practical investigation in science is generally accepted and it is recognised that excellent practical investigations promote better commitment and interest of learners, including the development of a number of inquiry skills (SCORE, 2008).

"It is important to examine the entire process of scientific investigation when studying the development of scientific inquiry strategies" (Duschl, Schweingruber & Shouse, 2007) highlighted. This process includes teaching strategies. Teaching methods that mostly involve learners during the learning activity through hands-on practical investigations are supposedly going to increase the development of science inquiry skills than methods that rely on inactive techniques, which are frequently used in the present standardised assessment-loaded educational setting (Minner et al, 2010). Learners are likely to adequately develop science inquiry skills during practical investigations when taught with a method that is compatible with them. Teaching methods usually translate into corresponding learning methods. The learning methods that were investigated in this study are individual practical investigations and group practical investigations. Both methods are commonly used in disadvantaged rural schools where resources are in limited supply.

By engaging in sustained investigations, learners are envisaged to learn scientific processes and recognise how these processes work together to generate new information (Singer, Marx & Krajcik, 2000). Singer et al, (2000) asserted that practical investigations provide opportunities for learners to design experiments, thereby using ideas related to independent, dependent and controlled variables. After identifying the variables, learners use them to hypothesise and define operationally how to use the variables to test the hypothesis.

Knowledge of practical investigations is based on the capacity to plan and design experiments (Hodson, 1992). According to Hodson (1992), planning investigations entails recognizing a particular question or difficulty for investigation, coming up with a hypothesis, establishing the dependent and independent variables, and so forth, which is mainly a concept-driven activity. Experiment designing includes considering all experimental procedure for investigation to be conducted (Hodson, 1992; 133); and includes the materials and instruments to be used and even making decisions about specific measurements and controlled conditions to be set. The Subject Assessment Guideline (SAG) for physical sciences (DoE, 2008:13) emphasises that investigations and experiments ought to focus on the practical work processes and science inquiry skills.

In addition, Grades 10–12 CAPS for the physical sciences aims to afford learners with practical investigating skills connected to physical and chemical phenomena (DBE, 2011). “The investigative skills that are relevant to the study of physical sciences are designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables” (DBE, 2011:8) , interpreting and reflecting. By doing practical investigation tasks learners in this study are expected to learn these investigative skills and thereby acquire the necessary science inquiry skills.

2.3 IMPORTANCE OF SCIENCE INQUIRY SKILLS IN SCIENCE TEACHING

Science inquiry skills are described as an understanding of methods and procedures of scientific investigation (Lan, Ismail & Fook, 2007:1). Temiz, Taşar and Tan (2006:1013) defined science inquiry skills as tactics and strategies scientists use during engagement in investigation to gain knowledge. Science inquiry skills are also defined as transferable skills that are applicable to many sciences, and that reflect the behaviours of scientists (Ergul, Simsekli, Calis, Ozdilek, Gocmencelebi & Sanli, 2011). Many studies have noted that science inquiry skills are effective in the teaching and learning of science (Harlen, 1999; Beaumont-Walters & Soyibo, 2001; Wilke & Straits, 2005); and learning these skills has become an important component of science curricula at all levels (Lan et al, 2007). The importance of these skills has led various countries (for example the United States and South Africa) to adopt the teaching of science inquiry skills in their science education curriculum.

There are two kinds of science process skills as categorised by Science – A Process Approach (SAPA). The first are basic science process skills (BSPS), such as observing, measuring and using numbers, and classifying. Basic science process skills provide the intellectual groundwork in scientific inquiry (Beaumont-Walters & Soyibo, 2001).

Integrated science inquiry skills are science process skills that assimilate (combine) a number of basic sciences process skills (Rezba, Sparague, Fiel, Funk, Okey, & Jaus, 1995). The development of these skills therefore requires the incorporation of more than one basic science process skill. Consequently, the use of integrated science process skills is dependent on the knowledge of the basic science skills (Onwu & Mozube, 1992). Integrated science process skills are therefore considered to be higher order thinking skills or cognitive processes. Scientist normally use integrated science process skills when designing and conducting investigations (Rezba, *et al*. 1995. Integrated science process skills (ISPS) include skills of controlling variables, formulating hypotheses and experimenting (Ergul et al, 2011), collecting and interpreting data, and defining variables operationally (Dlamini, 2008).

In this study, competence in integrated science inquiry skills is investigated because learners are expected to use the skills in practical tasks to acquire knowledge about the world we live in. In other words, competence in integrated science inquiry skills allows learners to formulate hypotheses, define controlled and operational variables and research problems in the natural world. However, researchers have documented that learners have difficulties in conducting systematic scientific investigations (Edelson, Gordin & Pea, 2004).

These difficulties range from designing the practical investigation, gathering data and analysing them, interpreting data, to communicating results. This study is an attempt to identify an effective learning method that could enhance the development of science inquiry skills by learners during practical investigations. In this study, the integrated science inquiry skills that are investigated are identifying and controlling variables, stating hypotheses, operational definitions, graphing and interpreting data, and experimental design as used by Kazeni (2005). Dlamini (2008, 15-16) gave a brief description of these skills:

- *Identifying and controlling variables*

Learners identify variables that can affect an experimental outcome, keeping most constant, while manipulating only the independent variable.

- *Stating a hypothesis*

It involves the use of information to make the best educated guess about the expected outcome of an experiment. Learners suggest tentative answers to problems before they start with their investigative procedure.

- *Operational definitions*

Learners state how to measure a variable in an experiment. It involves creating a definition, which is in the context of the learners' knowledge or experience, by describing what is done and observed.

- *Experimental design*

This involves designing and conducting an experimental science test with a control experiment. The experiment design must have a research question, hypothesis, variables (independent, dependent and controlled) and operational definitions. It also involves conducting the experiment and collecting data.

- *Graphing and interpreting data*

Drawing graphs and data interpretation require that learners make observations and record quantities (i.e. data) in an organised way. The data should enable learners to draw graphs and make conclusions from the obtained information.

In this study learners exposed to two practical investigation learning approaches were assessed on the development of the above five integrated science inquiry skills, to determine their performance competency. The learners' performance informed a judgment on the effectiveness of the learning approaches in the development of skills.

2.4 DEVELOPMENT OF INTEGRATED SCIENCE INQUIRY SKILLS DURING PRACTICAL INVESTIGATIONS

In this section the general learning of science inquiry skills is discussed. The integrated science inquiry skills under investigation in this study were referred to.

The development of science inquiry skills is “regarded as ‘learning how to learn’, because learners learn how to learn by thinking critically and using information creatively. Learners continue to learn when making discriminating observations, organising and analysing facts or concepts, giving reasons for particular outcomes, evaluating and interpreting results, drawing justifiable conclusions and predicting what would happen if anything were to be changed” (Martin, Sexton, Franklin & McElroy, 2001).

Dixon, Adams and Hynes (2001:163) identified three steps to be followed in the development of integrated science inquiry skills, as reported by Rapudi (2004). The steps followed for learners to develop the skill of controlling and identifying variables were as follows: i) Learners brainstormed the factors under investigation. ii) Learners provided a solution for the problem by setting up an investigation. Learners were guided to a conclusion in such a way that they required one factor at a time to compare. iii) Before learners begun collecting data, they identified the factors that they would keep constant and those that they would vary during the investigations. By doing so, learners were able to identify dependent and independent variable and subsequently provided the controlled variable(s).

The development of formulating hypothesis primarily follows the ability to identify the variables. Germann et al. (1996b: 199) stated that the hypothesis defines how the independent variable is manipulated and the answer to the dependent variable is predicted. The variable to be tested is the independent and the affected variable is the dependent. In acquiring the way in which a hypothesis is stated, learners need to formulate the relationship between the two variables in a cause and effect format.

Defining variables operationally is the other integrated science inquiry skill that depends on describing the variables. Operationally defining variables implies relating the dependent to independent variable. It is a way of defining how variables are manipulated and measured, including the controlled variables. Naming, describing and manipulating variables in a variety of contexts (Germann et al., 1996b) enhance learners’ competency in developing both the hypothesising and operational defining variables skills.

Designing a scientific experiment involves planning and carrying out an investigation (Mbano, 2004:105). Dlamini (2008:16) indicated that designing an experiment involves asking a research question, identifying and controlling variables, formulating hypothesis to be tested, conducting an experiment, data recording and interpreting. It is an integrated skill that embraces all the other skills.

The skill of graphing and data interpreting involves transforming recorded data into standard form, drawing graph(s) and subsequently discussing limitations, assumptions and explaining relationships. Guided practical investigations by facilitators in this study provided ample opportunities for learners to develop integrated science inquiry skills of identifying and controlling variables, hypothesising, defining variables operationally, designing experiments and graphing and interpreting data.

2.5 ASSESSMENT OF INTEGRATED SCIENCE INQUIRY SKILLS

The assessment of science inquiry skills involves a series of connected actions, experiences or changes, which occur internally within a learner, and can usually be demonstrated externally (Swain, 1989:252). SAG indicates that practical investigations are envisaged to measure performance at varying cognitive levels across all learning outcomes, with much more focus on learning outcome one (LO1). In physical sciences, LO1 deals with practical scientific inquiry and problem-solving skills, based on practical investigations. Harlen (1999) asserted that without the inclusion of science inquiry skills in science assessment, there will continue to be a mismatch between what our learners need from science and what is taught and assessed.

Science inquiry skills assessment should focus on certain aspects in an integrated manner: the learner's ability 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 (learning outcome 1). In addition, SAG states that assessment activities in practical investigations and experiments ought to be designed in such a way that learners are assessed on their competence in science process (inquiry) skills, such as planning, observing and gathering information, comprehending, synthesising, generalising, hypothesising, and communicating results and conclusions (DoE, 2008).

Rapudi (2004) reported various forms of assessment following practical activities. However, only two are related to this study: laboratory (investigation) reports; and paper and pencil tests.

Consequently, an investigation report and a paper and pencil test – known as the test for integrated science process skills – were used to assess learners' competence in integrated science inquiry skills. Both were evaluated using a written-response format. Subsequently, the evaluated investigation report and test scores informed learner performance. In turn, learners' performance on these assessments informed judgment on the effectiveness of the type of instructional method used to attain such achievement. In this study, the learners were given a real scientific problem, which required the use of inquiry skills to solve. Thereafter, competence in the five integrated inquiry process skills was assessed as explained.

2.6 RELATED STUDIES

A wide review of literature failed to identify any previous study that investigated the effect of group and individual practical investigation in the development of integrated science inquiry skills. Given that the development of integrated science inquiry skills is an important variable in this study, in this section studies related to learners' development of integrated science inquiry skills were examined.

Preece and Brotherton (1997) explored the effects of a science teaching intervention for a 28-week period that emphasised science process skills (basic and integrated) on student achievements. The intervention was provided to 43, 56 and 52 learners of 7, 8 and 9 years, respectively, on process skills based on *Science – A Process Approach* (SAPA). Results showed that significant difference (0.87) between the experimental and control group means existed for males only, when the intervention took place in year 8. This suggested that teaching science process skills over an extended period affects learner achievement and learner readiness at year 8.

Beaumont-Walters and Soyibo (2001) studied the level of performance of five integrated science process skills among Jamaican learners. The performance level was compared for Grades 9 and 10 learners who participated in the Reform of Secondary Education (ROSE) program and those who did not participate. It was found that the mean performance of ROSE learners was slightly higher than that of the non-ROSE learners.

The five integrated science process skills investigated in the ROSE study were identifying variables, formulating hypotheses, recording data, interpreting data and generalising. Results showed that the mean was significantly higher in recording data than the other four skills. Pearson's product moment correlation coefficients suggested that the correlation with other variables (grade level, school type, student type and socio-economic background) was statistically weak except in school type. This study also revealed that there were no relationships between learners' performance on integrated science process skills and school location and gender. The researchers also suggested that other factors that might play a significant role in variables related to performance of learners in integrated science inquiry skills development are learners' cognitive abilities, learning styles and teaching styles.

In the South African context, Rapudi (2004) investigated the effect of cooperative learning on the development of learners' science process skills in Limpopo. The results showed no effect on the development of learners' science inquiry skills of observation, controlling variables, graphing and experimenting in the group investigation method and jigsaw method of cooperative learning.

2.7 CONCEPTUAL FRAMEWORK OF THE STUDY

The conceptual framework of this study is based on constructivism theory. According to the constructivism model of learning, all our knowledge is the result of having constructed it (Trumper, 1997). The theory of constructivism is suitable for this study because when learners are developing science inquiry skills, they are likely to construct their own learning, either individually (radical constructivism) or in groups (social constructivism), to promote meaningful understanding of the skills. Robottom (2004) found that learning through constructivism theory was appropriate in the learning environment because it enhanced the understanding and involvement of learners, and developing a variety of skills, including science inquiry skills.

This study is framed on radical and social constructivism. Radical constructivism involves the notion that people develop their meanings on their own while interacting with the outside world. Social constructivism entails how individuals build knowledge and understanding about something after discussing and sharing ideas with others. In other words, new meanings of learnt concepts are formed after group discussion, which is equated with group (cooperative and collaborative) practical investigations in this study.

According to constructivism learning theory, learners come to the learning environment with their own ideas, not as *ta*bula rasa. Bishop (2007:5) defined tabula rasa as a state "whereby humans start out as empty sheets, devoid of any innate knowledge and come to know only through sense". Piaget and Inhelder (1969, translated by Weaver, 2000) also pointed out that learners do not come to schools as empty vessels; they have knowledge from their own observations and interactions with the world. The ideas and concepts that learners bring to the learning environment of various subjects, including physical sciences, are used to construct new knowledge, so that they have a meaningful understanding of what is to be learnt.

Science education researchers have investigated ways of teaching and learning that enhance the acquisition of science knowledge (Mathabatha, 2005). These teaching and learning methods are based on fundamental concepts including constructivism. The teaching and learning strategies used in physical sciences in the Revised National Curriculum Statement (RNCS) in Grades 10–12 include the use of practical investigations to develop science inquiry skills. This may occur while performing the task individually (radical constructivism) and/or in a group format (social constructivism). In this study, individual practical investigation and group practical investigation represent radical and social constructivism ways of learning, respectively. The notions of radical and social constructivism are discussed below.

Radical constructivism

Radical constructivism is a theory of learning that supports the notion that knowledge development is an adaptive process, resulting from the individual learner's interaction or experimentation with the world, and/or with an issue that needs to be learned or solved. To develop integrated science inquiry skills, learners should create their own model (Von Glasersfeld, 1995) of variables, formulating hypothesis, designing experiments, interpreting data, and so forth, during practical investigation activities as a form of learning. In other words, learners develop science inquiry skills during practical investigation tasks by building their own models as individuals during the learning process and are able to communicate these in written reports.

Learners need to be exposed to an environment in which they are active participants. "Knowledge is not passively received either through the senses or by a way of communication, but actively built up by the cognising subject" (Rahman, Jalil & Hassan, 2008:22). According to DBE CASS requirement in physical sciences, learners are required to conduct practical investigations either individually or in groups but submit individual written reports. Written reports are assessed to determine the level at which the integrated science inquiry skills have been developed.

Based on the notion of radical constructivism, learners were involved in individual practical activities, after which their competence in integrated science inquiry skills was measured to determine the effectiveness of the treatment in enhancing their development of these skills.

Social constructivism

Social constructivists regard the acquisition of knowledge and skills as a consequence of social interactions (Doolittle & Camp, 1999). During social interactions, individual treatment learners share information collectively in a dialogue. The shared experiences in the teaching-learning environment occur through learner-educator interactions, cooperative learning groups and classroom discussions.

Some scholars (Osborne, 1997) have pointed out that the benefits of cooperative learning include increased learner achievement and skills development. Learners in cooperative groups could develop integrated science inquiry skills through group dynamics. On the other hand, shortcomings have been reported. For instance, Lord (2001) reported that group work is time consuming and too informal for technical materials to be used effectively by a group. Karagiorgi and Symeou (2005) argued that not all social contexts, such as group practical investigation, can promote constructivist learning, and equally, not all constructivist learning depends on social contexts.

In this study, cooperative investigation as a learning strategy to develop integrated science inquiry skills was explored. In group practical investigations, learners planned and designed the investigations as a team and each member had shared responsibly (Dlamini, 2008). Learners work together in sharing resources and ideas while developing integrated science inquiry skills.

Social constructivism is suited to this study because learners doing practical investigations in small groups needed to work together to develop integrated science inquiry skills. Learning to develop science inquiry skills as a group is important as a social construct. This is supported by Vygotsky (1962) in his discussion proposal, in which he indicated that learning can best be achieved in an interactive setting such as discussion and hands-on activities. Despite performing practical investigations in a group, group members were assessed individually. In summary, this study compared the relative effectiveness of individual practical investigation (radical constructivism) and group practical investigation (social constructivism) learning methods on the development of integrated science inquiry skills.

2.8 CHAPTER SUMMARY

This chapter discussed how practical investigations contribute to the development of integrated science inquiry skills. Teaching strategies affect the ways in which learners can develop science inquiry skills during practical investigations tasks. Individual and group works were found to be used mostly in teaching practical activities in science subjects in order to develop science inquiry skills.

Various studies were conducted to evaluate the level of developed science inquiry skills in relation to different aspects. The studies assisted in developing a conception framework of this study. This conceptual framework is centred on constructivism, based on how learners construct meaning to develop integrated science inquiry skills when doing practical investigations. The next chapter looks into the research methodology of this research study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter focuses on the research design and methodology employed in this study. The research method and design constitute a plan for conducting the research, which involves the study context, sampling procedure and participants, instrumentation, data collection procedures for answering the research question(s), pilot study, the main study and ethical considerations.

3.2 RESEARCH METHOD AND DESIGN

The method used in this study is a mixed-method research approach. This may be defined as "the type of research which merges features of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative terminologies, data collection and analysis procedures, as well as inferences) for the broad purposes of breadth and depth of understanding" (Johnson, Onwuegbuzie & Turner (2007:123). The mixed-method approach followed the QUAN/Qual approach (Creswell, 2009). The primary data collected to answer research question 1 were numerical (quantitative) in nature. The quantitative data provided information for statistically comparing the performances of participants in the individual and group practical investigations. This qualitative information was important in explaining the outcome of the quantitative results. As Kazeni (2012) stressed, the mixed-method research is vital in that numerical data from the quantitative approach and the narratives from the qualitative approach complement each other for greater insight into and better understanding of the results.

The study design was experimental. Experimental designs are studies that investigate the relationship between 'cause and effect' (Kumar, 2011). The experimental design type preferred for the study was comparative design. An experimental comparative design is a study in which the population is divided randomly into a number of treatment groups to be tested and each group is established to a baseline (pre-test or before observation) for the dependent variable (Kumar, 2011:120). In this study, the treatment models are the learning methods, and the baseline is the pre-test using the test instrument (test of integrated science process skills (TIPS)). The degree of change in the dependent variables of the population groups can be compared to establish the relative effectiveness (Kumar, 2011) of the treatment modalities.

In addition, the outcome of the research was quantified, giving a measurement for the dependent variable, which is learner performance or achievement in integrated science inquiry skills. McMillan and Schumacher (2010) pointed out that a research is experimental only if the outcome can be measured, and quantified, and inferential statistics are used to compare the two groups. In this study, the learners' performances or achievement averages between the individual and the group treatments were compared to establish their relative effectiveness in developing integrated science inquiry skills. Dependent variables based on mean scores achieved by treatment groups were used as performance measures to determine whether the difference between mean scores was statistically significant in order to respond to the investigative research question.

3.3 STUDY VARIABLES

The variables that were studied in the research are indicated in table 3.1 below.

Table 3.1 Variables of the study

	Type of variable	**Variables**
1	Independent variables (treatment models)	1.1 Individual practical investigation 1.2 Group practical investigation
2	Dependent variables (also referred to as 'learning outcomes')	2.1 Ability to identify and control variables 2.2 Ability to state hypotheses 2.3 Ability to operationally define variables 2.4 Ability to design experiments 2.5 Ability to draw graphs and interpret data

The independent variables were manipulated so that the outcome in the dependent variables was determined. The five dependent variables were derived from the five integrated science inquiry skills of identifying and controlling variables, stating hypotheses, operationally defining variables, designing experiment, and graphing and interpreting data.

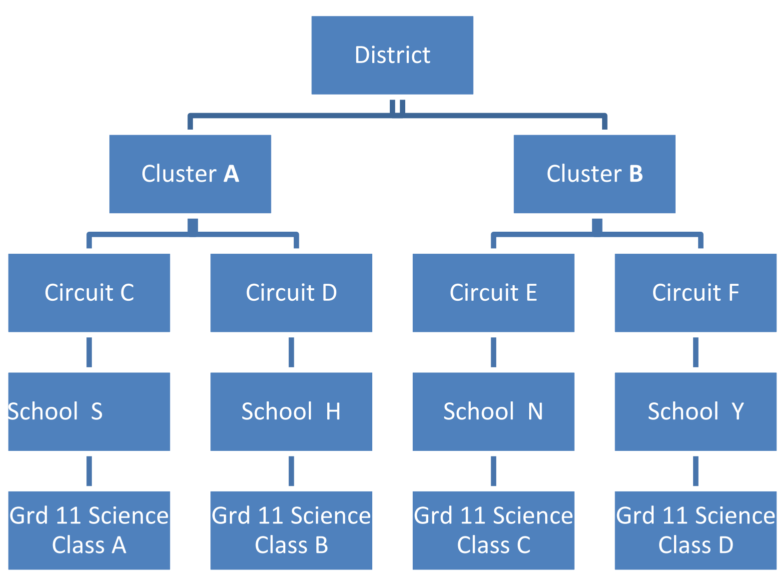
3.4 STUDY CONTEXT

The study was conducted in Mopani Education District in Limpopo, South Africa. Limpopo has five education districts. The districts cover a wide area (± 300 km radius), and each district consists of five or six clusters. Each cluster is composed of four to six circuits, and a circuit consists of approximately thirty primary and secondary schools. In each circuit, the number of secondary schools is between eight and fifteen. Mopani district has five cluster circuits. The district was chosen because of convenience to the researcher. Two cluster circuits were used as the study area, as outlined in the sampling procedure below.

3.5 SAMPLING PROCEDURE AND PARTICIPANTS

Two top performing clusters from Mopani district were identified, based on analysis of the past three years' Grade 12 results (2010–2012). In each cluster, two high performing circuits were identified from these results. In each circuit, one of the high performing schools – in terms of better Grade 12 physical sciences average results – was selected. Four schools participated in the study. The high performing schools were selected in order to have a large number of participants (large samples), since high performing schools are assumed to attract more learners. High performing schools were also assumed to have learners with a greater range of learning cognitive levels (that is, above average, average and below average learners). The type of sampling used for clusters, circuits and schools was purposive because it focused on high performance. The purposive sampling used in this study is represented in figure 3.1.

Figure 3.1 Representation of structure of sampled line institutions from district level to class



The population of this study was Grade 11 learners doing physical sciences. Grade 11 learners taking physical sciences as a subject at these four schools comprised the study sample.

Learners participated individually or in groups of three. Learners from each of the four schools were randomly assigned to individual practical investigations or group practical investigation class. In a random sample, each individual had an equal chance of being included (Rambuda & Fraser, 2004: 11) in the group. Therefore, the characteristics of each individual in the sample reflected the characteristics of the population (Leedy, 1993:201). This affected the level of development of integrated science inquiry skills in all the groups equally (Kumar, 2011) and minimised the influence of extraneous factors. Randomly assigning subjects is a powerful technique when equating groups in experimental research because it increases the internal validity of the study (Johnson & Christensen, 2011:303). Kumar (2011) supported the concept that random assignment ensures comparability.

In this study, the random assignment process followed the systematic sampling approach. For each Grade 11 class, a class list was compiled of all volunteer participants in no specific order. The sampling interval was determined as three (3). In every sampling interval (a small group of participants), the first participant was assigned to individual practical investigation class and the next three participants formed a small group of practical investigation members. The ratio for individual : group practical investigation was averaged at 1 : 3 for the total participants. A total of 319 Grade 11 learners, comprising 138 males and 181 females, participated in this study. Learner participants in individual and group practical investigations (groups) were 79 and 240, respectively. Table 3.2 (below) shows the number of participating learners.

Table 3.2 Number of participants according to schools and treatment group

School	Males	Females	Total	Participants in individual practical investigation	Participants in group practical investigation	Total
S	45	69	114	28	86	114
H	38	40	78	19	59	78
N	34	33	67	17	50	67
Y	21	39	60	15	45	60
TOTAL	**138**	**181**	**319**	**79**	**240**	**319**

Key: S, H, N, Y= Represent the names of the four schools

This study compared the mean scores performance of learners from individual and group practical investigation classes.

3.6 INSTRUMENTATION

Pre-tests and post-tests were administered using a test instrument referred to as the test of integrated science process skills (TIPS), which was developed and validated by Kazeni (2005). The Instrument consisted of 30 multiple-choice items based on natural science content. Each question consisted of a stem statement and four possible answers, of which one was correct. The items tested the level of achievement in integrated science process skills, namely identifying and controlling variables (eight items: numbers 2, 6, 16, 19, 25, 28, 29, and 30); stating hypotheses (four items: numbers 8, 20, 23, and 26); operational definitions (six items: numbers 1, 7, 10, 18, 21, and 22); graphing and interpreting data (nine items: numbers 4, 5, 9, 11, 12, 14, 17, 24, and 27); and experimental design (three items: numbers 3, 13, and 15). Performance was assessed with the marking memorandum of the test instrument. The participants' marks were recorded.

In addition, two natural sciences-based practical investigations were conducted and participants submitted two practical investigation reports using a specific report writing format (Appendix D). The reports revealed the development of integrated science inquiry skills by individual treatment learners. A marking rubric (Appendix E) and marking memoranda (Appendices $F_{1,}$ F_2) were used to assess the investigation reports. The pre-test, post-test, and practical report scores were used to assess learners' performance in integrated science inquiry skills.

To collect qualitative data, a questionnaire (Appendix G) was drawn. The focus of the questionnaire was on obtaining qualitative feedback in order to support the statistical findings (quantitative results) of the study. The questionnaire consisted of open-ended questions. These questions were based on pre-determined themes to help support the research findings. The themes were premised on a) learners' interest in the assigned practical investigation learning method (question ii)); b) learners' views on the acquisition of science process skills (questions iii), iv) and vi)); c) learners' views on the challenges of doing practical investigations and grasping scientific concepts (questions v) and xi)); d) learners' opinions on understanding practical investigations and science (questions vii and ix)); e) learners' opinions on their performances between pre-test and post-test (question x)); and f) their perceptions of the effectiveness of the assigned learning method (question viii)).

3.6.1 Reliability and validity of instruments

Reliability and validity are important concepts in a research study, whether the approach is quantitative or qualitative. Threats to both reliability and validity of instruments need to be minimised in a particular study. The subsequent texts discuss the reliability and validity of the instruments used in this study.

3.6.1.1 Reliability of study instruments

Reliability is "the extent to which results are consistent over time and an accurate representation of the total population under study" (Joppe, 2000:4). "If the results from a study instrument can be reproduced under a similar methodology and conditions, then the research instrument is considered reliable". Joppe stated that "Instrument reliability is a way of ensuring that any instrument used for measuring experimental variables gives the same results every time".

The internal consistency reliability coefficient of the test instrument was 0.81 and thus was very reliable, as determined by Kazeni (2005), because the acceptable range of reliability is (0.7–1.0) (Hinkle, 1998). The test instrument's standard error of measurement was a relative small value of 7.07, which was considered reliable (Nitko, 1996). The readability level of the test instrument is 70.3. This was a 'fairly easy readability range', according to Flesch's reading ease scale (Klare, 1976). Instrument reliability was not determined in this study, since it is assumed that the reliability carried out by Kazeni (2005) on the research instrument was conducted in Limpopo on learners with similar characteristics and environmental factors to those who participated in this study.

The TIPS instrument item indices of difficulty, according to science process skills, were 0.43, 0.42, 0.35, 0.36 and 0.42 for identifying and controlling variables, stating hypotheses, operational definitions, experimental design and graphing and interpreting data, respectively. The overall index of difficulty was 4.0, showing that most learners might find the test difficult.

The internal consistency reliability of practical investigation tasks was done with the split-halves test method. This method obviously involves dividing the test into two halves (Shuttleworth, 2009), and performance on the two halves is analysed statistically. The split-halves test gives a measurement value of between zero and one, with one representing a perfect correlation, and a zero representing no correlation at all. If there is a weak correlation between the two halves, then there is a reliability challenge with the test or instrument.

The practical tasks items of the pilot study were split into two groups, the odd-numbered (half-test 1) and even-numbered (half-test 2). Every participating learner therefore had two sets of scores. The scores obtained by each participant were compared and correlated using the Pearson product-moment coefficient as used by Kazeni (2005), as follows:

$$R = \frac{N \sum X \dot{Y} - (\sum X)(\sum \dot{Y})}{N \sum X^2 - (\sum X)^2] [N\sum \dot{Y}^2 - (\sum \dot{Y})^2]}$$

Where:

r = correlation between the two half-tests (half-test 1 and half-test 2)

N = total number of scores

$\sum X$ = sum of scores from the half-test 1

$\sum \dot{Y}$ = sum of scores from the half-test 2

$\sum X^2$ = sum of the squared scores from the half-test 1

$\sum \dot{Y}^2$ = sum of the squared scores from the half-test 2

$\sum X\dot{Y}$ = sum of the product of the scores from the half-test 1 and half-test 2

The Pearson product-moment coefficient (r) had to be adjusted to reflect the full-length task correlation coefficient of the practical investigation task instrument by using the Spearman-Brown prophecy formula as reflected by Kazeni (2005) when developing the test instrument, as follows:

R = 2r / (1 + r), where R = estimated reliability of the full-length task

r = the actual correlation between the two half-tests

Finally, the standard error of measurement (SEM) was calculated using the formula:

SEM = SD $\sqrt{1 - r}$, where SEM = standard error of measurement

SD = standard deviation of the task scores

r = reliability coefficient

The pilot study results (Appendix H) were used to calculate the value of the estimated reliability of the full-length task (R) using the split-half method above. The calculated R value was 1 for both practical investigation tasks, with N = 24, X = 300 and $\dot{Y}$ = 356; and N = 24, X = 273 and $\dot{Y}$ = 348 for practical investigation task 1 and 2, respectively. From R = 2r / (1 + r) the Pearson product-moment coefficient (r) = 1. The SEM = 0, since r = 1. Since r = 1, this represented a perfect correlation for practical investigation tasks 1 and 2. The perfect correlation meant that the practical investigation tasks were reliable. A reliability test was not conducted for the questionnaire since it consisted mostly of open-ended questions.

3.6.1.2. Validity of study instruments

In experimental research design, variables may cloud each other if validity issues are not taken care of. Vogt (2007:117) defined validity as 'the truth or accuracy of the research'. Dlamini (2008) stated that validity refers to the relevance of the research instrument and the appropriateness of the interpretations made from the test scores. This means that the validity of the instrument is the extent to which the instrument measures what it purports to measure. Muijs (2004:65) added that the results obtained from an instrument that does not measure what the researcher intends to measure will be meaningless.

There are various types of validity with regard to research instrumentation. They include content, construct and face validity. In this study, content validity was used to validate the following instruments: TIPS, scientific practical investigation tasks, marking rubric and a questionnaire. Content validity was relevant for several reasons. It dealt with the concepts of integrated science inquiry skills in practical investigations and ensured that these practical investigation tasks and the marking rubric contained appropriate items to assess and measure the learners' development of integrated science inquiry skills during the research study.

Content validity

Content validity refers to whether the contents of the question(s) and items of an instrument are adequate to measure the concepts that the researcher is trying to measure (Muijs, 2004:66). In addition, Cohen, Manion and Morrison (2000:109) said that an instrument used to collect data must show that it fairly and comprehensively covers the items that it purports to measure.

TIPS has been validated with a content validity value of 0.98, which is within the acceptable standard value of ≥ 0.7 (Kazeni, 2005). The TIPS instrument developed by Kazeni (2005) and used in this study was not further validated as the context and contents were similar to those for the validation by Kazeni.

The content validity for scientific practical investigation tasks, the marking rubric and questionnaire was assessed by enlisting three expert colleagues in science education, who made a judgment about the degree to which the instruments of the practical investigation task items matched the objectives or specifications. The experts comprised two curriculum advisors for physical sciences and one for life sciences with more than seven years' experience in the field. They have thorough knowledge of physical and life sciences from former education colleges and currently for FET band schools. The criteria for the experts' judgments were whether i) the practical tasks were relevant to the practical investigation for Grade 11 as prescribed by the CAPS documents; there were no factual errors; and all relevant information was provided for the participant to conduct the practical investigations; and ii) the marking rubrics had appropriate level descriptors (0–3 levels); the integrated science inquiry skills were weighted appropriately; and descriptions' scores had no factual errors and were appropriate to the understanding level of Grade 11 learners.

All three experts found that the practical investigation tasks and the marking rubric were valid and could be used effectively in the research study. One expert raised concern about the zero (0) rating scale in the marking rubric, and whether it would be appropriate if the rating scale started at one (1) so that all participants could get a reward (mark) for any attempt to respond. After discussions, consensus was reached to include the zero (0) to accommodate a rating for participants who failed to respond.

A content validity assessment of the questionnaire was carried out to obtain the opinions of the experts about the questionnaire. The criteria for judgment were based on whether the questionnaire had adequate simple language relevant to Grade 11 learners, contained ambiguous or double-barrelled question(s), asked leading questions or presumption-based questions, and provide feedback on the types of questions (difficult or easy) and format (open or closed). All three experts were satisfied that the questionnaire was relevant for collecting in-depth information about the research investigation and would explain the quantitative results.

3.7 PILOT STUDY

A pilot study was conducted at Vhembe District School Q in Limpopo. The school was selected from one of the Malamulele cluster circuit schools using purposive sampling (good performing school that had sufficient Grade 11 science learners and two sets of science laboratories).

The purpose of the pilot study was, first, to find out how long it would take the learners to complete the practical investigations and write the report; and, second, to determine the challenges and successes of administrating and facilitating the practical investigation tasks, writing reports, writing integrated science process skills tests (pre- and post-tests) and collecting qualitative data using questionnaires; and, third, to measure the reliability of practical investigation tasks 1 and 2 and the marking rubric (3.6.1.1).

The purpose of piloting the questionnaire was to pre-test its success. The following functions were considered during questionnaire piloting as outlined by Cohen et al, (2009:341): to check the clarity of the questionnaire items, instructions and layout, and to check the time taken to complete the questionnaire.

In the pilot study 41 physical sciences learners in Grade 11 from Malamulele East Circuit's school participated. The participating learners were (19) males and (22) females from Grade 11 who were taking physical sciences as a subject. Learner participants were randomly sampled to either small-group class or individual class participation using systematic random sampling.

3.7.1 Administration of the pilot study

The researcher applied for permission to conduct the pilot study from the provincial education department. After permission had been granted, other applications were forwarded to the circuit office and the principal of the sampled school. Dates for conducting practical investigations were agreed upon with the principal and the head of the science department at the school. The dates were for pre-test, two sessions for conducting practical investigation tasks and post-test by participants.

The purpose of the study was explained to the learners, and was followed by information about their right to participate or to decline without repercussions. Two experienced science educators were hired as research assistants. The research assistants were trained to deal with the administration of the ISPS tests, assisting with the practical investigation tasks and marking tasks.

Before the administration of TIPS as a pre-test, the participants were sampled into two groups. After the pre-test, one group performed the two practical investigation tasks in small groups of four (i.e. group participants) and the other group as individuals in two separate laboratories.

The time taken to complete both practical investigations and report writing was calculated from the average time taken by the first and last five participants to complete the tasks. The average duration for the completion of practical investigation tasks and for report writing was 60 minutes (i.e. two hours). These time allocations were used for administration of the tasks during the main study.

TIPS (which had already been used for the pre-test) was given as a post-test to all participants after the practical investigation tasks and submission of reports. The post-test was administered two weeks after the pre-test. The time gap was regarded as being sufficient for participants to have developed integrated science inquiry skills during the two practical investigations and long enough for them to forget their previous responses (Kazeni, 2005). The pre-test, practical investigation reports and post-test were evaluated by the research assistants, and scores were allocated. The researcher moderated 10% of the overall scripts from both the individual and group treatment learners. Minor discrepancies in the evaluation were noted and discussed with the research assistants, and these were corrected in all the scripts.

The organisation of questionnaires was based on group self-administration in the presence of the researcher (assistant) and was conducted on the same day as the post-test. The collective method that was carried out when the captive audiences were in the classrooms had two successes. It ensured a good response rate, and more questions were completed on one occasion, that is, data were gathered from many respondents simultaneously, as supported by Cohen et al. (2009). The time taken to complete the questionnaire was averaged at twenty five minutes.

3.7.2 Results and discussion of the pilot study

This section involves a discussion of the pilot study TIPS scores and practical investigation report results.

3.7.2.1 Test of integrated science process skills scores results

Forty one (41) participants were involved in the pilot study and their performances were determined. The participants' scores were computed in Microsoft Excel tabular format, as represented in table 3.3.

Table 3.3 Extract of participants coding showing pre-test, post-test and practical reports scores of pilot study (Appendix H).

Learner Code	Gender	PRE-TEST SCORES						POST-TEST SCORES						PRACTICAL REPORTS SCORES		
		ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	PR1(40)	PR2(40)	PRAV(40)
1PMI	M	4	3	1	1	0	9	6	2	2	7	0	17	24	27	25.5
2PMI	M	4	0	1	3	2	10	4	1	1	4	1	11	23	*	11.5
3PFM	F	3	1	2	3	2	11	3	0	0	4	1	8	15	*	7.5
4PFI	F	3	0	2	2	1	8	4	2	2	2	1	11	12	16	14
5PMG	M	3	2	3	4	0	12	4	2	4	1	0	11	30	23	26.5

6PMG	M	1	0	0	3	1	5	4	1	2	5	1	13	23	21	22
7PFG	F	1	1	1	2	0	5	4	3	1	4	2	14	19	32	25.5
8PFG	F	3	1	1	2	1	8	3	0	2	4	1	10	30	21	25.5

Key: Participant code:

1PMI represents (1 = Learner number 1, P = Pilot school, M = Male and I = Individual treatment /practical investigation)

7PFG represents (7 = Learner number 7, P = Pilot school, F= Female and G = Group treatment /practical investigation)
Gender: M = Male F = Female
ISPS1 (8) = Integrated Science Process Skill 1 (to identify and control variables): score out of 8 marks
ISPS2 (4) = Integrated Science Process Skill 2 (to state hypothesis): score out of 4 marks
ISPS3 (6) = Integrated Science Process Skill 3 (to operationally define variables): score out of 6 marks
ISPS4 (9) = Integrated Science Process Skill 4 (to design experiments): score out of 9 marks
ISPS5 (3) = Integrated Science Process Skill 5 (to draw and interpret data): score out of 3 marks
PR1(40) = Practical report 1: score out of 40 marks
PR2(40) = Practical report 2: score out of 40 marks
PRA(40) = Practical report average (PR1 + PR2 divided by 2): score out of 40 marks
* = Task not submitted

Results showed that the participants' performance was low in the pre-test because no learner managed to obtain a total score above 20. Most practical report scores were above 15, which showed a good performance.

The analyses were then used to compare the performances between the individual practical investigation and the group practical investigation classes, using descriptive and inferential statistics as represented in tables 3.4, 3.5 and 3.6.

Table 3.4 Descriptive statistics of pilot study pre-test scores

Treatment	N	Minimum	Maximum	Mean	Std. Deviation	Std. Error Mean
Group	28	2	12	6.93	2.610	0.493
Individual	13	6	15	9.08	2.783	0.772

The number of participants (N) was 41, divided into two groups. The group participants numbered 28 and individual participants 13. The group minimum score out of 30 was 2 and the maximum score was 12, whereas the individual minimum score was 6 and the maximum score was 15. The range for the individual participants was 9, which is slightly smaller than the group participants' of 10. The mean of the individual participants of 9.08 is larger than that of group participants of 6.93. The standard deviation of the group participants and individual participants was 2.610 and 2.783, respectively. The standard deviation shows the standardised measure of the dispersal of the scores, that is, how far from the mean (average) each score is (Cohen et al, 2009:512). Table 3.4 shows the standard error of mean (SEM) of individual participants and group participants of 0.772 and 0.493, respectively. The SEM represents a measure of sampling error of the standard deviation of the theoretical distribution of sample means (Cohen et al, 2009). The SEM gives the finest estimate of sampling error.

The results were analysed using the SPSS (Statistical Package for Social Sciences) program to compare the mean scores difference between the two participating groups for the pre-test and post-test. An independent sample t-test was used for the comparison, which is presented in table 3.5.

Table 3.5 Independent sample t-test for pre-test scores of individual and group treatments

		Levene's test for equality of variances		t-test for equality of means						
									95% Confidence interval of difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
ISPS Scores	Equal variances assumed	.047	.830	2.403	39	.021	2.148	.894	.340	3.957
	Equal variances not assumed			2.346	22.158	.028	2.148	.916	.250	4.047

Levene's test for equality of variances contains F statistics, F = 0.047 and significance value (p-value), Sig = 0.830 as shown in table 3.5 above. Since the significance level is greater than 0.05, the group variances can be treated as equal, and the assumption of homogeneity of variance was not violated.

The purpose of the pre-test was to ensure that the participants were equivalent before intervention or treatment was applied, as suggested by Jackson (2011:229). From Levene's test of equal variances, the significance level (Sig.) = 0.830. It follows that the row of 'equal variances assumed' must be used, since p>0.05. The results of the independent t-test were reported as by Cohen et al. (2009:545). The mean of the individual treatment (mean = 9.08, standard deviation = 2.783) differed significantly statistically (t = 2.403, df = 39, two-tailed (p = 0.021) than the group treatment mean (mean = 6.93, standard deviation = 2.610) of pre-test learners' performance. The results showed that significant difference between the mean performance of the individual treatment and group treatment before the actual treatments commenced. The mean of individual treatment was significantly higher than the group treatment.

Tables 3.6 and 3.7 represent the pilot study results for post-test data.

Table 3.6 Descriptive statistics of pilot study post-test scores

Treatment	N	Minimum	Maximum	Mean	Std. deviation	Std. error mean
Group	28	4	19	13.92	5.139	1.425
Individual	13	7	23	11.64	3.880	.733

The range for the individual participants was 16, higher by 1 than the group participants' range of 15, as shown in table 3.6. The mean of the group participants was 13.92 and greater than individual participants of 11.64. The descriptive statistics were used to compare the mean scores using the independent sample t-test. In order to determine whether there is significant difference between the means of the two groups' performances, the sig (2-tailed) level is compared with the alpha (α) level = 0.05. If sig (2-tailed) level > 0.05, there is no significant difference statistically between the means.

Table 3.7 Independent sample t-test of pilot study post-test scores of individual and group treatments

	Levene's test for equality of variances		t-test for equality of means						
								95% Confidence interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Equal variances assumed	2.119	.153	1.578	39	.123	2.280	1.445	-.643	5.204
Equal variances not assumed			1.423	18.612	.171	2.280	1.603	-1.079	5.640

Levene's test for equality of variances has a significance value (p-value), Sig = 0.153 as indicated in table 3.7. Since the significance level was greater than 0.05; the group variances was treated as equal and the assumption of homogeneity of variance was not violated. The mean of group treatment (M = 13.92, SD = 5.139) did not differ statistically significantly (t = 1.578, df = 39, two-tailed p = 0.123) from the individual treatment mean of (M = 11.64, SD = 3.880) on post-test scores.

After the post-test results, there was no significant difference between the scores of individual and group treatments. However, the pre-test results showed that there was significant difference between the means of individual treatment and group treatment. The mean of the individual treatment was higher than (statistically significant difference) the group treatment mean. Inferring from pre-test and post-test mean results, the group mean performance improved significantly in the post-test compared with the individual treatment.

3.7.2.2 Practical investigation report results

The descriptive statistics results of practical reports scores are provided in table 3.8. They were obtained by adding the two scores achieved by a participant, divided by two, from practical reports submitted after the participants had performed the practical investigation tasks.

Table 3.8 Descriptive statistics of pilot study practical reports scores of individual and group treatments

Treatment	N	Minimum	Maximum	Mean	Std. deviation	Std. error mean
Individual	13	7.5	32	20.58	9.044	2.508
Group	28	16	31	24.34	3.825	.723

The mean score of the individual treatment class was lower than the group mean score by 3.76 as shown in table 3.8. Table 3.9 provides inferential statistics to show whether the 3.76 difference of the two mean scores was statistically significant.

Table 3.9 Independent sample t-test of pilot study practical reports scores

	Levene's test for equality of variances		t-test for equality of means						
								95% Confidence interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Equal variances assumed	33.161	.000	-1.887	39	.067	-3.762	1.994	-7.795	.271
Equal variances not assumed			-1.441	14.033	.171	-3.762	2.610	-9.360	1.835

The results of the independent sample t-test showed that the mean score of the group treatment (mean = 24.34, standard deviation = 3.825) did not differ significantly statistically (t = 1.441, df = 14.033, two-tailed (p = 0.171)) from the individual treatment mean score (mean = 20.58, standard deviation = 9.044) of practical report performance results.

In summary, the pilot study achieved what was outlined in the purpose. The time needed to conduct practical investigation tasks and to write up the reports was established. Administration logistics, such as planning and preparing for laboratory equipment, time and space management, materials for recording and reporting practical investigations, were observed, managed and noted. The practical investigation task reliability was established. In addition, the pilot study results highlighted the problems of insufficient resources and educational policies which prohibit researchers from conducting prolonged experiments with learners during contact time. As a result, the researcher provided sufficient materials and equipment for the practical activities, and limited the intervention to after school hours for duration of two hours.

3.8 MAIN STUDY

3.8.1 Procedure for the main study

In each of the four sampled schools, Grade 11 physical sciences learners were organised in one venue after they had agreed to participate. These stakeholders were consulted and accepted that the investigation should be conducted: the participants' parents, learners (participants/subjects), school management, and school governing body, circuit and district officials, and the DoE at provincial office. At the venues, learners were guided through the objectives and ethical procedures involved in the study. Participants wrote the pre-test based on the test instrument (Appendix A). The purpose of the pre-test was to determine the mean scores of the two groups and ensure that the groups were equivalent before the intervention. Additionally, the mean scores of the two pre-test groups were compared to ensure that the randomisation process was effective. The pre-test was administered after normal school hours and took about 60 minutes to complete. A marking memo (Appendix B) was used to evaluate the participants' performances.

Before the pre-test, participants in each participating school were randomly assigned to two groups: the individual practical investigation class, and the group practical investigation class. After the pre-test, participants from the two classes conducted two practical investigation tasks, individually and as small groups of three, respectively. The two practical investigation tasks (Appendices C_1, C_2) were based on topics in the natural sciences FET programme. The facilitators of the practical investigation tasks were two research assistants. These research assistants were experienced trained science educators. To achieve random allocation of the research assistants to the two groups, a coin was flipped for allocation to each school to assure fairness and uniformity of facilitation. The research assistants were trained on issues regarding the practical activity tasks, facilitation on practical investigation tasks, precautionary measures in dealing with science equipment and class management. Their training was done by the researcher a week before the commencement of the pilot study and took three hours.

The practical investigation tasks and practical report writing (Appendix D, report format) were conducted after normal school hours, and took between 120 and 140 minutes. Two practical tasks were performed per school on different days. The second practical investigation tasks were conducted two weeks after the initial ones. Practical reports were written and handed in on the day that the practical investigation was conducted. The individual practical investigation class conducted two tasks without assistance from peers or a research assistant, after which they were required to write practical reports. The group practical investigation class conducted the same practical investigation tasks in groups of three. The group treatment learners worked collaboratively by assigning responsibilities to each group member and then collectively discussing how each task will be carried out. Further, the findings from the experiments were collectively discussed and agreed upon before writing the practical reports individually. This allowed the researcher to measure the effect of group interactions on the individual learner's development of integrated science inquiry skills. A standardised marking rubric (Appendix E), accompanied by a marking memo (Appendices $F_{1,}$ F_2), was used to evaluate the practical reports. After conducting the two practical investigations, both treatments wrote a post-test based on the test instrument. A questionnaire was administered immediately after the post-test.

To maximise control over extraneous variables (factors that could invalidate the causal conclusions (McMillan & Schumacher, 2010:259)), the following measures were carried out:

- Participating learners were randomly assigned to individualised and cooperative groups.
- To remove the effect the current subject educator might have on participants, research assistants were used as facilitators in both the individual practical investigations and group practical investigations.
- To avoid distractions, the learning environments were controlled, in the sense that the two groups were in different but similar laboratory environments (each school has two laboratories). This meant a complete separation of the two class groups.
- To ensure the uniformity of instructions given to the two class groups, the first instructions and any other relevant information about the research and activities were disseminated in the same room, before the two class groups were separated.

3.8.2 Data analysis procedure

The quantitative data gathered in this study were analysed using descriptive and inferential statistics. Descriptive statistics transform a set of numbers or observations into indices that describe or characterise the data (McMillan & Schumacher, 2010:149) and are used to organise, summarise, and describe observations. In this study, the data were described using univariate analysis. Univariate analysis summarises data in terms of a single variable, mostly the dependent variable, when different groups are compared.

In univariate analysis, mean and standard deviation were used to analyse the data. Both mean and standard deviation were calculated using the SPSS program to compare the performances in pre-tests and post-tests of the two groups. In addition, the independent sample t-test was performed to test the significance differences between the post-test mean scores of the individual and the group practical investigation classes.

The independent sample t-test is an inferential statistical test used to determine whether there is statistically significant difference between the mean scores of two independent (unrelated or unpaired) groups. (Independent groups mean that the members of one group are not members of the other group.) To validate the independent sample t-test results, these six assumptions must hold. i) The dependent variable should be measured on a continuous scale. (The learners' performance scores were between 0 and 30 marks in both pre- and post-test and practical investigation report scores were measured between 0 and 40 marks.) ii) Two independent variables are required. (Individual and group practical investigations learners were independent because each learner was represented by a unique code). iii) There should be independent observation, that is, no participant should be placed in more than one group. (Learners remained in their own groups after random sampling.) iv) There must not be significant outliers. (All scores were less than the maximum available marks.) v) There must be normal distribution of the dependent variable. (The Shapiro-Wilcox test of normality using SPSS was used.) Assumption v) is presented in chapter 4 on pre- and post-test learners' performance scores and practical investigation report score distribution before results analysis. vi) There should be homogeneity of variances. (SPSS Levene's test for homogeneity of variances was used.) Assumption vi) is imbedded in the independent sample t-test table of results analysis.

The independent sample t-test was used in this study to test the null hypothesis, which is that 'there is no significant difference in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations'. The hypothesis testing was based on these steps: determine the alpha (α) level, where alpha was set at $\alpha = 0.05$; and perform the SPSS data analysis to determine the t-statistical value, degree of freedom (df) value and the critical probability value (Sig.). These three values were used to accept or reject the null hypothesis. In accepting or rejecting the null hypothesis, the result could be interpreted that the independent variable (teaching-learning modalities) did or did not affect the dependent variable (achievement mean scores in the TIPS).

Qualitative data collected through the questionnaire responses were analysed using content analysis. Participants' responses were categorised into six themes and coded. The six themes were i) learners' interest in the assigned practical investigation learning method; ii) learners' views on the acquisition of science process skills; iii) learners' views on the challenges of practical investigations; iv) learners' opinions of understanding practical investigations and science; v) learners' opinions of performance between pre-test and post-test; and vi) learners' perceptions on the effectiveness of assigned learning method. Similar views for a given theme were regarded as a general view of the two groups (individual and group practical investigations). The recorded overall views of the two groups were compared and evaluated in relation to the quantitative data to triangulate information and clarify quantitative data (Kazeni, 2012). These general views and comparisons formed part of the research study findings.

Practical investigation reports were used to assist in understanding which integrated science inquiry skills learners might have developed. The analysis was done using five themes as derived from the dependent variables. The themes were i) ability to identify and control variables; ii) ability to state hypotheses; iii) ability to operationally define variables; iv) ability to design experiments, and v) ability to draw graphs and interpret data.

3.9 ETHICAL CONSIDERATIONS

Certain ethical considerations required by the Faculty of Education of the University of Pretoria were adhered to. These ethical requirements are discussed below.

Full disclosure, informed consent and voluntary participation

The procedures and time needed for the study were explained to the school management teams and participants in order to be open and transparent about the study. Potential participants were informed of the purpose and nature of the research study to ensure that they could evaluate the processes and methods and make an informed decision about whether to participate or not in the study. It was indicated that participation in the study was voluntary. Potential participants were provided with letters to their parents for informed consent and to obtain their agreement for learners to participate in the research study. Other consents were sought from the education management system. This study obtained the approval and cooperation of the district senior manager, circuit managers, school managers, educators and the department of education: head of department's office.

No harm or risk to participants

Learner participants were assured of the highest standards of ethical issues, health and safety during their engagement in the research study. This was done by providing participants with safety procedures for the practical investigation tasks. All important precautions were elaborated in advance and even during practical investigations. The materials and equipment were at one accessible point so that there was free movement when collecting them. Facilitators were responsible for distributing materials for the practical activities, and ensuring that they were used in a safe way.

Privacy, *anonymity* and *confidentiality*

The privacy of the participants was protected. Access to participants' responses, behavioural characteristics and other information related to the study was restricted to the researcher. To ensure privacy, the principles of confidentiality, anonymity and appropriate data storage were adhered to. Anonymity and confidentiality requirements were taken into consideration by using codes and synonyms to represent the names of the participants and their schools.

3.10 CHAPTER SUMMARY

This chapter outlined the research design and methodology used to plan and execute the research study effectively. It discussed the steps taken for sampling participants, validating the instruments, data collection procedure, how data was analysed and ethical considerations were addressed. The following chapter deals with the research study results.

CHAPTER 4

STUDY RESULTS

4.1 INTRODUCTION

In this chapter, the results of the study are presented. The quantitative results are followed by the qualitative results, which support the descriptive and inferential statistics of the quantitative results. The quantitative result presentation includes the pre-tests, practical reports and post-tests, whereas the qualitative results are presented as narratives of learners' views about the two learning methods and the development of inquiry skills.

4.2 QUANTITATIVE RESULTS

The research study results sought to answer the investigative question: 'How do group practical investigations compare with individual practical investigations in learners' development of integrated science inquiry skills?' The quantitative part of the study focused on this investigative research question: 'Is there any difference in the integrated science inquiry skills developed by learners exposed to individual practical investigations and those exposed to group practical investigations?

In an effort to answer the investigative research question, the following null hypothesis was tested: 'There is no significant difference in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations.' This was meant to determine the significance of performance differences in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations using TIPS. The results for testing the null hypothesis were obtained by comparing the descriptive and inferential statistical results between the performances of learners exposed to individual practical investigations and group practical investigation learning approaches in post-tests using TIPS scores.

4.2.1 Comparison of learner performance in integrated science inquiry skills before the intervention

At the beginning of the study, it was necessary to find out whether there was any difference in the competencies of the two groups in science inquiry skills. Competence of learners in inquiry skills prior to the treatment was determined by comparing their performance on the TIPS in a pre-test based on these five integrated science process skills (ISPS):

ISPS1 = skills to identify and control variables
ISPS2 = skills to state hypothesis
ISPS3 = skills to operationally define variables
ISPS4 = skills to design experiments
ISPS5 = skills to draw and interpret data

An independent sample t-test was used to compare the mean scores performance of learners on TIPS. The pre-test results were used to establish competency equivalence on learners' abilities on the five integrated science inquiry skills at the beginning of the study prior to the treatment. In order to meet the assumption of normality for using the inferential statistics, a normal distribution test was conducted, which yielded the following results.

4.2.1.1 Normal distribution test of individual treatment learners' performance on test of integrated science process skills pre-test

The pre-test scores for both treatment groups were tested for normality distribution. Figure 4.1 represents the individual treatment learners' pre-test scores distribution.

Figure 4.1 Graphical presentation of normality assumption of individual treatment pre-test scores

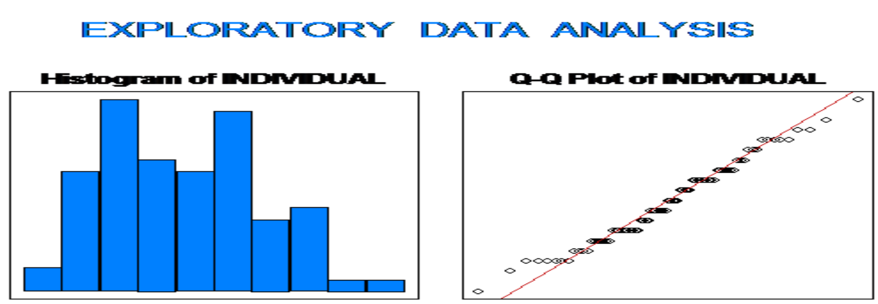


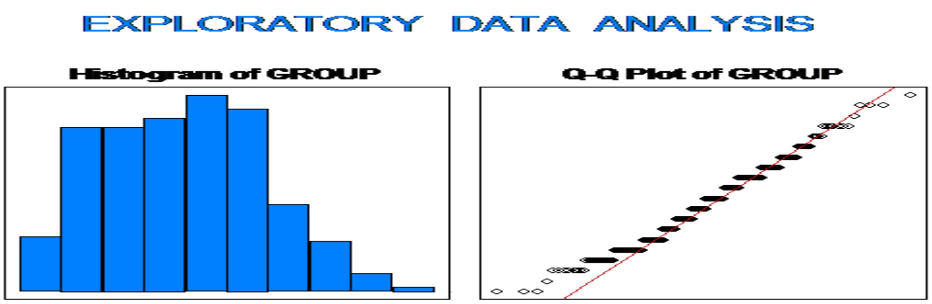
Figure 4.1 shows that the data for individual pre-test scores did not seriously depart from normality. This can be seen from the histogram, which is approximately symmetric, and from the points in the

Q-Q plot, which lie close to the fitted line. The pre-test scores for individual treatment therefore conformed to normality assumptions.

4.2.1.2 Normal distribution test of group treatment learners' performance on test of integrated science process skills pre-test

The normality test for the group treatment pre-test scores indicates that the scores did not seriously deviate from normality. This was evident from the histogram, which is approximately symmetric and from the points in the Q-Q plot, which lie close to the fitted line, as shown in figure 4.2. This can be further supported because the dataset is large and the sampling distributions of group pre-test scores converge to normal. The pre-test data for group treatment therefore conformed to normality assumptions.

Figure 4.2 Graphical presentation of normality assumption of group treatment learners pre-test scores



4.2.1.3 Comparison of the overall pre-test performance of individual and group treatment learners on test of integrated science process skills

The comparison of overall pre-test performance of individual and group treatment learners is based on TIPS scores for the 79 individual and 240 group treatment learners. Table 4.1 shows the descriptive statistics of the overall performance of the individual and group practical investigation learners' scores.

Table 4.1 Descriptive statistics of individual and group treatment learners' overall performance on TIPS pre-test

	Treatment	N	Mean	Std. deviation	Std. error mean
ISPS Scores	Individuals	79	12.86	4.104	.462
	Groups	240	12.34	3.956	.255

The total mark for pre-test scores was 30. The individual performance and group treatment learners' performance means were 12.86 and 12.34, respectively. These results were used to determine whether there was a significant difference in the competence of the two treatment groups in inquiry skills before the learning treatment modes were introduced. The individual treatment class mean score on pre-test was higher than the group treatment learners mean score by 0.52. The standard deviation and standard error mean values of the individual treatment learners' performance were also higher compared with the group treatment learners' performance by 0.15 and 0.21, respectively. The standard deviation values showed that the scores of individual treatment learners were slightly more spread out than the group treatment learners' scores. Levene's test for the equality of variance and the t-test for the equality of means were used to compare the performance of the two groups on TIPS. Table 4.2 shows the results of the comparison.

Table 4.2 Independent sample t-test of overall pre-test performance of the individual and group treatments

		Levene's test for equality of variances		t-test for equality of mean s						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference Lower	Upper
ISPS Scores	Equal variances assumed	.310	.578	1.002	317	.317	.519	.518	-.500	1.538
	Equal variances not assumed			.984	129.075	.327	.519	.528	-.525	1.563

Levene's test for equality of variances shows a significant level of (Sig.) = 0.578. Equal variances were assumed since p> 0.05, as shown in table 4.2. With regard to the t-test for equality of means, table 4.2 shows that the individual treatment learners' performance pre-test mean of (mean = 12.86, standard deviation = 4.104) did not significantly differ (t = 1.002, df = 317, two-tailed p = 0.317) from that of group treatment learners' performance mean scores of (mean = 12.34, standard deviation = 3.956). This is because the 2-tailed significance level (sig.) p = 0.317 was greater than p = 0.05.

4.2.1.4 Comparison of pre-test performance of individual and group treatment learners on specific integrated science inquiry skills

The descriptive statistics and independent sample t-test results of individual and group treatment classes on pre-test ISPS1 to ISPS5 are shown in tables 4.3 and 4.4.

Table 4.3 Descriptive statistics for pre-test scores of ISPS1 of individual and group treatments

	Treatment	N	Mean	Std. deviation	Std. error mean
ISPS1	Group	240	3.5000	1.45504	.09392
	Individual	79	3.6835	1.58958	.17884

The total mark for ISPS1 was 8. Table 4.3 shows that the individual treatment mean score for ISPS1 on pre-test was higher than the group treatment mean score.

Table 4.4 Independent sample t-test for pre-test scores of individual and group treatments on ISPS 1

		Levene's test for equality of variances		t-test for equality of mean s						
									95% Confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
ISPS1	Equal variances assumed	2.878	.091	-.950	317	.343	-.18354	.19318	-.56361	.19652
	Equal variances not assumed			-.909	123.883	.365	-.18354	.20200	-.58337	.21628

Comparison of individual and group treatment mean scores on ISPS1 pre-test shows that the individual treatment mean score of ISPS1 of (mean = 3.6835, standard deviation = 1.58958) did not differ significantly statistically (t = 0.950, df = 317, two-tailed p = 0.343) from that of group treatment mean score of (mean = 3.50, standard deviation = 1.45504) as shown by the independent sample t-test results in table 4.4.

With a total mark of 4, table 4.5 shows the descriptive statistics for ISPS2 of both the individual and the group treatment mean scores. The individual treatment class (mean = 1.519) performed better than the group treatment class (mean = 1.504).

Table 4.5 Descriptive statistics for pre-test scores of ISPS2 of individual and group treatments

	Treatment	N	Mean	Std. deviation	Std. error mean
ISPS2	Group	240	1.5042	.91477	.05905
	Individual	79	1.5190	.91792	.10327

Based on table 4.6, Levene's test of equal variances comparison of independent t-test indicates that the individual treatment mean score of (mean = 1.5190, standard deviation = 0.91792) did not differ significantly statistically (t = 0.125, df = 317, two-tailed p = 0.901) from that of group treatment mean score of (mean = 1.5042, standard deviation = 0.91477) on ISPS2.

Table 4.6 Independent sample t-test for pre-test scores of individual and group treatments on ISPS 2

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference Lower	Upper
ISPS2	Equal variances assumed	.047	.829	-.125	317	.901	-.01482	.11876	-.24847	.21883
	Equal variances not assumed			-.125	132.705	.901	-.01482	.11896	-.25013	.22049

The individual treatment mean score for ISPS3 on pre-test scores of 2.3291 was higher than the group treatment scores mean of 2.1917 as shown in table 4.7, with a total mark of 6.

Table 4.7 Descriptive statistics for pre-test scores of ISPS3 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. Error mean
ISPS3	Group	240	2.1917	1.31165	.08467
	Individual	79	2.3291	1.23747	.13923

The independent sample t-test on ISPS3 in table 4.8, shows that the individual treatment mean score of ISPS3 of (mean = 2.3291, standard deviation = 1.23747) did not differ significantly statistically (t = 0.819, df = 317, two-tailed p = 0.413) from that of group treatment mean score of (mean = 2.1917, standard deviation = 1.31165).

Table 4.8 Independent sample t-test for pre-test scores of individual and group treatments on ISPS 3

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference Lower	Upper
ISPS3	Equal variances assumed	.205	.651	-.819	317	.413	-.13745	.16782	-.46763	.19273
	Equal variances not assumed			-.844	140.106	.400	-.13745	.16295	-.45960	.18471

Descriptive statistics of individual and group treatment classes shows mean score for ISPS4 in table 4.9. The total mark for ISPS4 was 9, and group mean score was higher than the individual treatment scores mean.

Table 4.9 Descriptive statistics for pre-test scores of ISPS4 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. error mean
ISPS4	Group	240	4.0125	1.64782	.10637
	Individual	79	3.9241	1.76702	.19881

Table 4.10 shows the independent t-test results for ISPS4 where the group treatment mean score of ISPS4 of (mean = 4.0125, standard deviation = 1.64782) did not differ significantly statistically (t = 0.406, df = 317, two-tailed p = 0.685) from that of individual treatment mean score of (mean = 3.9241, standard deviation = 1.76702). The 2-tailed significance level (sig.) p = 0.685 was greater than α level = 0.05.

Table 4.10 Independent sample t-test for pre-test scores of individual and group treatments on ISPS 4

		Levene's test for equality of variances		t-test for equality of means						
									95% Confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
ISPS4	Equal variances assumed	.446	.505	.406	317	.685	.08845	.21765	-.33977	.51666
	Equal variances not assumed			.392	125.686	.696	.08845	.22547	-.35776	.53466

The individual treatment mean score for ISPS5 is 0.2718 higher than the group mean score, as shown in the descriptive statistics table 4.11.

Table 4.11 Descriptive statistics for pre-test scores of ISPS5 of individual and group treatments

	Treatment	N	Mean	Std. deviation	Std. error mean
ISPS5	Group	240	1.1333	.89567	.05782
	Individual	79	1.4051	.87000	.09788

The mean score difference was used on independent sample t-test table 4.12 to see whether the difference is statistically significant between individual and group treatments on ISPS5.

Table 4.12 Independent sample t-test for pre-test scores of individual and group treatments on ISPS 5

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference Lower	Upper
ISPS5	Equal variances assumed	.136	.713	-2.355	317	.019	-.27173	.11537	-.49871	-.04475
	Equal variances not assumed			-2.390	136.497	.018	-.27173	.11368	-.49654	-.04692

According to the results shown in table 4.12, Levene's test of equal variances shows that the individual treatment mean score of ISPS5 of (mean = 1.4051, standard deviation = 0.870) differed significantly statistically (t = 2.355, df = 317, two-tailed p = 0.019) from that of group treatment scores (mean = 1.1333, standard deviation = 0.89567). The results implied that individual treatment learners were more competent in ISPS5 than the group treatment learners, prior to the treatment application.

4.2.2 Comparison of learners' performance in integrated science inquiry skills after the intervention

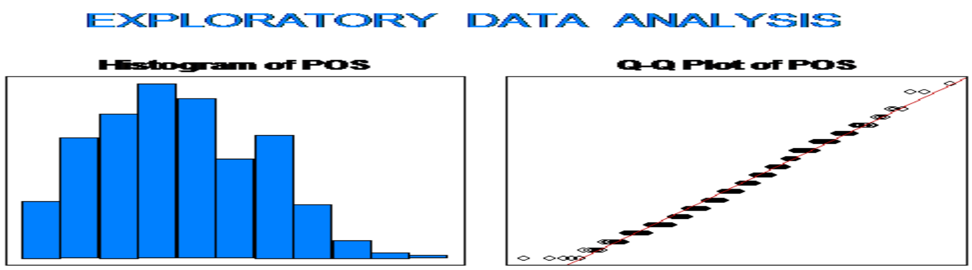
The post-intervention results were important in determining the outcome of investigative question 1 of the research study. Learners' competences in integrated science inquiry skills after the intervention were compared, using the independent sample t-test. The results are presented in two sections. These are a comparison of performance on TIPS post-test and on practical reports. Both learners' performance results were based on the five integrated science process skills (4.2.1).

In comparing learner performances using inferential statistics, it is important that the distribution of learners' scores should be tested for normality assumptions to avoid the violation of the independent sample t-test, which may cause type I error. Learners' performance scores for both the individual and group treatments were therefore tested for normality, using the Shapiro-Wilcox test. The results are displayed in subsections 4.2.2.1 and 4.2.2.2.

4.2.2.1 Normal distribution test of individual treatment learners' performance on test of integrated science process skills post-test

Post-test scores distribution analysis showed that normality assumption of individual treatment learners' performance scores was not seriously violated as presented graphically in figure 4.3.

Figure 4.3 Graphical presentation of normality assumption of individual treatment post-test scores

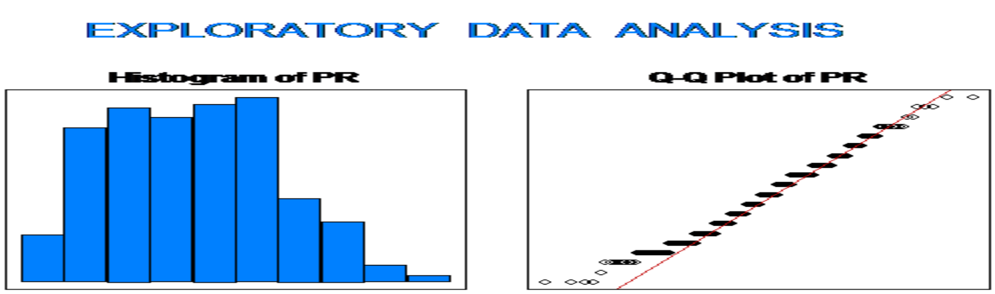


The Q-Q plot shows that the post-test scores were approximately normally distributed since the values lie close to the fitted line and the histogram was approximately symmetrical.

4.2.2.2 Normal distribution test of group treatment learners' performance on test of integrated science process skills post-test

Figure 4.4 below shows the results of the normality test for group treatment learners' performance on the post-test. The results show that normality assumption for using t-test method to analyse group treatment scores data was not seriously violated. The density function showed that the data were approximately normally distributed and symmetrical from the histogram. The Q-Q plot displayed that most values lie close to the fitted line and affirmed that the data came from normal distribution.

Figure 4.4 Graphical presentation of normality assumption of group treatment post-test scores



4.2.2.3 Comparison of pre-test and post-test performance of individual and group treatment learners on test of integrated science process skills

The pre- and post-test performances of the individual and group treatments were compared to determine whether there was improvement in learners' competence in science inquiry skills after the intervention. Sections i) and ii) present the results of these comparisons.

i) Comparison of pre-test and post-test performance of individual treatment learners on test of integrated science process skills

The 79 individual treatment learners' performances in the pre- and post-tests were analysed descriptively, as shown in table 4.13. The post-test mean score for individual treatment was slightly greater than the pre-test mean score based on a total mark of 30.

Table 4.13 Descriptive statistics for pre-test and post-test scores of individual treatment

	Treatment	N	Mean	Std. Deviation	Std. Error mean
Individual	Pre-test	79	12.8608	4.10358	.46169
	Post-test	79	12.8987	4.77868	.53764

Based on Levene's test of equal variances of the independent sample test (table 4.14), the individual treatment class post-test mean score (mean = 12.8987, standard deviation = 4.77868) did not statistically differ significantly (t = 0.957, df = 156, two-tailed p = 0.957) from that of pre-test mean score of (mean = 12.8608., standard deviation = 4.10358). The 2-tailed significance level (sig.) p = 0.957 was greater than α level = 0.05. The results signified that there was no significant improvement in learners' performance in ISPS after they performed practical investigations individually.

Table 4.14 Independent sample t-test for pre-test and post-test scores of individual treatment

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference: Lower	Upper
Individual	Equal variances assumed	1.680	.197	-.054	156	.957	-.03797	.70867	-1.43781	1.36186
	Equal variances not assumed			-.054	152.516	.957	-.03797	.70867	-1.43806	1.36211

ii) Comparison of pre-test and post-test performance of group treatment learners on test of integrated science process skills

Descriptive statistics for pre-test and post-test scores of group treatment in table 4.15 show the pre- and post-test mean scores of 240 group treatment learners. Out of TIPS total mark of 30, the calculated mean score for the post-test was slightly higher than the pre-test by a difference of 0.18

Table 4.15 Descriptive statistics for pre-test and post-test scores of group treatment

	Treatment	N	Mean	Std. deviation	Std. error mean
Group	Pre-test	240	12.3417	3.95581	.25535
	Post-test	240	12.5167	4.00101	.25826

The independent sample t-test results for pre-test and post-test scores of group treatment in table 4.16 indicate that the post-test mean score of (mean = 12.5167, standard deviation = 4.00101) did not statistically differ significantly (t = 0.482, df = 478, two-tailed p = 0.630) from that of pre-test mean score of (mean = 12.3417, standard deviation = 3.95581). The 2-tailed significance level (sig.) p = 0.630 was greater than α level = 0.05.

Table 4.16 Independent sample t-test for pre-test and post-test scores of group treatment

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
									Lower	Upper
Group	Equal variances assumed	.006	.936	-.482	478	.630	-.175	.363	-.88863	.53863
	Equal variances not assumed			-.482	477.93	.630	-.175	.363	-.88863	.53863

4.2.2.4 Comparison of the overall post-test performance of individual and group treatment learners on test of integrated science process skills

The individual and group treatment learners' mean performance for TIPS post-test scores were 12.90 and 12.52, respectively, as shown in table 4.17. The mean value of the individual treatment learners' performance was higher than the group treatment learners by 0.38.

Table 4.17 Descriptive statistics of individual and group treatment learners' overall performance in TIPS post-test

	Treatment	N	Mean	Std. Deviation	Std. error mean
ISPS scores	Individual	79	12.90	4.779	.538
	Group	240	12.52	4.001	.258

The post-test mean values were important since they determine whether the null hypothesis, 'There is no significant difference in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations', should be accepted or rejected after performing the independent sample t-test statistics.

The comparison of overall post-test performance using the independent sample t-test showed that Levene's test significant level was (Sig.) = 0.030 in table 4.18. Therefore, equal variances were *not* assumed since p< 0.05. Values from 'equal variances *not* assumed' were used to report the results. The individual treatment learners' performance post-test mean of (mean = 12.90, standard deviation = 4.779) did not statistically differ significantly (t = 0.641, df = 116.132, two-tailed p = 0.523) from that of group treatment learners performance mean score of (mean = 12.52, standard deviation = 4.001). The post-test results meant that the null hypothesis is supported that there is no significant difference in the development of integrated science inquiry skills by learners exposed to individual and group practical investigations, based on results from TIPS.

Table 4.18 Independent sample t-test of the overall post-test performance of the individual and group treatments

		Levene's test for equality of variances		t-test for equality of means						
									95% Confidence interval of the difference	
		F	Sig.	t	df	Sig.(2-tailed)	Mean difference	Std. error difference	Lower	Upper
ISPS Scores	Equal variances assumed	4.774	.030	.700	317	.484	.382	.546	-.691	1.455
	Equal variances not assumed			.641	116.132	.523	.382	.596	-.799	1.563

4.2.2.5 Comparison of post-test performance of individual and group treatment learners on specific integrated science inquiry skills

The comparison of group and individual treatments on post-test ISPS1 to ISPS5 learners' performance is presented using descriptive statistics and independent sample t-test as shown in the following tables.

The descriptive statistics shown in table 4.19 represent the individual treatment mean score of post-test ISPS1, which was higher than the group treatment mean score. The mean score for the treatment group was based on a total mark of 8.

Table 4.19 Descriptive statistics for post-test scores of ISPS1 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. Error mean
ISPS1	Group	240	3.5583	1.54593	.09979
	Individual	79	3.6709	1.63081	.18348

The post-test mean score on ISPS1 of individual treatment class of (mean = 3.6709, standard deviation = 1.63081) did not statistically differ significantly (t = 0.554, df = 317, two-tailed p = 0.580) from that of group treatment mean score of (mean = 3.5583, standard deviation = 1.54593) as shown in table 4.20. The 2-tailed significance level (sig.) p = 0.580 was greater than α level = 0.05. This meant that after the treatment there was no significant difference in the performance of both treatment groups on ISPS1.

Table 4.20 Independent sample t-test for post-test scores of individual and group treatments on ISPS 1

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference: Lower	Upper
ISPS1	Equal variances assumed	.772	.380	-.554	317	.580	-.11255	.20329	-.51252	.28741
	Equal variances not assumed			-.539	127.332	.591	-.11255	.20886	-.52584	.30073

From a total mark of 4, the group treatment mean score on post-test ISPS2 was higher than the group treatment mean score as shown in table 4.21 by a difference of 0.174.

Table 4.21 Descriptive statistics for post-test scores of ISPS2 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. Error mean
ISPS2	Group	240	1.5917	.95939	.06193
	Individual	79	1.4177	.88590	.09967

According to independent sample t-test results on table 4.22 below, the group treatment mean score of ISPS2 of (mean = 1.5917, standard deviation = 0.95939) did not statistically differ significantly (t = 1.424, df = 317, two-tailed p = 0.155) from that of individual treatment mean score of (mean = 1.4177, standard deviation = 0.88590). Both treatment groups did not significantly improve their mean scores achievement after treatment on ISPS2.

Table 4.22 Independent sample t-test for post-test scores of individual and group treatments on ISPS 2

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference Lower	Upper
ISPS2	Equal variances assumed	1.546	.215	1.424	317	.155	.17395	.12217	-.06641	.41431
	Equal variances not assumed			1.482	142.898	.140	.17395	.11734	-.05801	.40590

Table 4.23 presents the descriptive statistical results of individual and group treatment mean scores for ISPS3 on post-test. The individual mean score was greater than the group treatment mean score and the total mark for ISPS3 was 6.

Table 4.23 Descriptive statistics for post-test scores of ISPS3 of individual and group treatments

	Treatment	N	Mean	Std. deviation	Std. error mean
ISPS3	Group	240	2.2417	1.22386	.07900
	Individual	79	2.4810	1.36683	.15378

The results in table 4.24 show the independent sample t-test results of individual and group treatment classes for ISPS3. The individual treatment mean score of (mean = 2.4810, standard deviation = 1.36683) did not statistically differ significantly (t = 1.384, df = 121.833, two-tailed p = 0.169) from that of group treatment mean score of (mean = 2.2417., standard deviation = 1.22386).

Table 4.24 Independent sample t-test for post-test scores of individual and group treatments on ISPS 3

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference: Lower	Upper
ISPS3	Equal variances assumed	5.925	.015	-1.464	317	.144	-.23935	.16351	-.56104	.08235
	Equal variances not assumed			-1.384	121.833	.169	-.23935	.17289	-.58159	.10290

Based on a total mark of 9, the individual treatment mean score (4.1392) for ISPS4 on the post-test was greater than the individual treatment mean score (4.0333) as shown in table 4.25.

Table 4.25 Descriptive statistics for post-test scores of ISPS4 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. Error mean
ISPS4	Group	240	4.0333	1.80160	.11629
	Individual	79	4.1392	2.03643	.22912

Post-test mean score of individual treatment of (mean = 4.1392, standard deviation = 2.03643) did not statistically differ significantly (t = 0.438, df = 317, two-tailed p = 0.661) from that of group treatment mean score of (mean = 4.0333., standard deviation = 1.80160) for ISPS4 calculated using the independent sample t-test as presented in table 4.26 below.

Table 4.26 Independent sample t-test for post-test scores of individual and group treatments on ISPS 4

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference: Lower	Upper
ISPS4	Equal variances assumed	1.467	.227	-.438	317	.661	-.10591	.24154	-.58113	.36931
	Equal variances not assumed			-.412	120.751	.681	-.10591	.25694	-.61460	.40278

The independent sample t-test results confirm that on ISPS4, there was no significant difference in learners' performance on the learning science inquiry skill of designing experiments between individual and group treatment classes.

Descriptive statistics for post-test scores on ISPS5 for individual and group treatments show that the individual treatment mean score on post-test ISPS5 was greater than the group treatment mean score as shown in table 4.27. The total mark for ISPS5 post-test scores was 3.

Table 4.27 Descriptive statistics for post-test scores of ISPS5 of individual and group treatments

	Treatment	N	Mean	Std. Deviation	Std. Error mean
ISPS5	Group	240	1.0917	.88687	.05725
	Individual	79	1.1899	.84847	.09546

The significant level of (sig.) = 0.285 as shown in table 4.28 shows that equal variance were assumed since p>0.05 in independent sample t-test analysis. From the analysis, it follows that on ISPS5 the individual treatment mean score of 1.1899 did not statistically differ significantly from that of group treatment mean score of 1.0917.

Table 4.28 Independent sample t-test for post-test scores of individual and group treatments on ISPS 5

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference: Lower	Upper
ISPS5	Equal variances assumed	1.146	.285	-.863	317	.389	-.09821	.11383	-.32217	.12575
	Equal variances not assumed			-.882	138.352	.379	-.09821	.11131	-.31829	.12188

Based on table 4.28, on ISPS5 the learners in individual and group treatment classes performed equally after being exposed to the two learning modalities on practical investigations.

4.2.3 Comparison of learners' performance on practical investigation reports

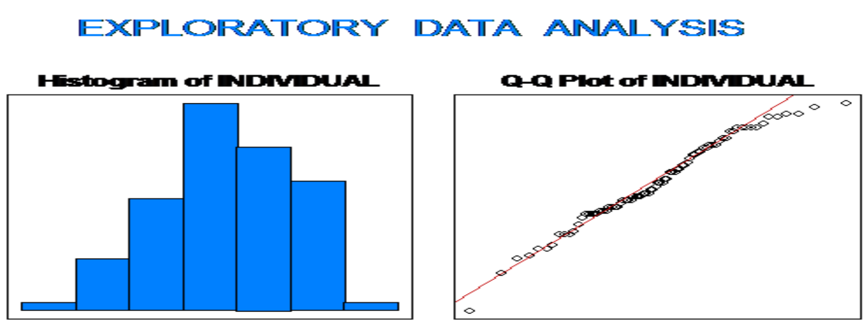
The comparison of practical investigation reports performance is based on the scores learners obtained after the assessment of practical reports. Mean scores of the two treatment groups were analysed using descriptive and inferential statistics to determine whether there was a significant difference in the performances of individual and group treatment classes.

4.2.3.1 Normal distribution test of individual treatment learners' performance on practical investigation reports scores

Normality distribution tests for individual and group practical investigation task report scores were conducted using the Shapiro Wilcox test of SPSS. The results of the test are presented in figures 4. 5 and 4.6 below.

The exploratory data analysis showed the histogram and the Q-Q plot for normality assumption of individual treatment learners' scores of practical investigations reports in figure 4.5. The analysis from the Shapiro-Wilcox test revealed that the normality assumption was not seriously violated. This was evident from the Q-Q plot, which showed that the data were approximately normally distributed, since the values lie close to the fitted line. The histogram also showed an approximate 'bell-shaped' figure and supported the assumption that the scores were normally distributed.

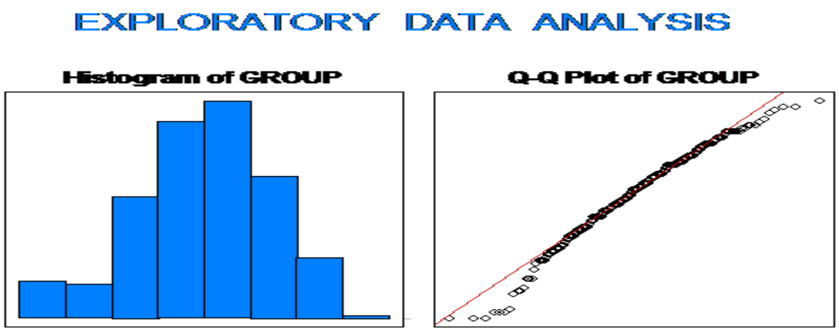
Figure 4.5 Graphical presentation of normality assumption of individual practical report scores



4.2.3.2 Normal distribution test of group treatment learners' performance on practical investigation reports scores

The Q-Q plot graphic in figure 4.6 displays values lying close to the fitted line, whereas the histogram shows an approximate 'bell-shaped' score distribution . The graphs indicate that the normality assumption for using an independent sample t-test method to analyse the data was not completely violated.

Figure 4.6 Graphical presentation of normality assumption of group practical reports scores



4.2.3.3 Comparison of learners' performance on practical investigation reports

The practical investigation report scores (table 4.29) show that 79 individual practical investigation and 240 group practical investigation learners submitted their reports.

Table 4.29 Descriptive statistics of practical report scores

Treatment	N	Minimum	Maximum	Mean	Std. Deviation	Std. error mean
Individual	79	0.500	30.500	19.190	6.241	0.7021674
Group	240	0.000	35.500	20.169	7.329	0.4730849

The group practical investigation learners' mean score was higher than that of the individual treatment learners by 0.979. The inferential statistical analysis of practical report mean scores is presented in table 4.30.

Table 4.30 Independent sample t-test of practical report scores

	Levene's test for equality of variances		t-test for equality of means						
								95% Confidence interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Equal variances assumed	0.7925	0.7644	1.0663	317	0.2871	0.97888	0.8466689	- 0.82725	. 2.78500
Equal variances not assumed			1.1561	154.506	0.2494	0.9788	0.8466689	-0.69371	2.65146

An independent sample t-test shows that the group treatment learners' practical performance report mean score (20.169) did not statistically differ significantly from the individual treatment learners' performance mean score (19.190), as reflected in table 4.30 above. The results revealed that the individual and group treatment classes performed similarly on practical investigation reports. These results complemented the performance of the two classes on TIPS.

4.3 QUALITATIVE RESULTS

Qualitative data were used to address research question 2, stated as follows:

> How can the development of these science inquiry skills by learners exposed to the two practical investigation learning methods be explained?

Qualitative data from practical reports (4.3.1) and questionnaires (4.3.2) were used to address the second research question. The responses from practical reports were used to determine whether there were differences in the development of science inquiry skills between learners exposed to individual practical investigations and those exposed to group practical investigations. Information from the questionnaires was used to augment the data from practical reports.

The following texts present data obtained from practical investigation reports as provided by learners after conducting the practical investigation tasks. Practical investigation task 2 was conducted after practical investigation task 1. Practical investigation task 1 was based on physics content: 'Plan, design and conduct an investigation to find out whether the changing of length of the pendulum has an effect on the period of a pendulum.' Practical investigation task 2 was based on chemistry content: "Plan, design and conduct an investigation to find out whether the amount of heat produced will depend on an increase in the concentration of HCl when HCl reacts with excess Zn."

4.3.1 Learners' responses from practical investigation reports

These learners' responses based on the integrated science inquiry skills are extracts from their written practical reports. The data are arranged so that responses to task 1 are presented first, followed by responses to task 2. In addition, for each integrated science inquiry skill considered, individual responses are presented first, followed by group responses. Codes were used to represent learner's responses. The codes comprise three identifying numbers and three letters per learner (e.g. 001YIF: 001 means learner 1; YIF: Y is the letter representing the school; I =

individual practical investigation learner; F = gender (female). The criteria used to determine the number of learner responses were based on the representativeness of the answer to the individual and group treatment classes on a given integrated science inquiry skill. Responses from male and female learners were considered equally, including diverse views on learners' understanding of learning science inquiry skills and practical investigations in order to provide in-depth representations on how learners develop inquiry skills. However, no fixed number of learners' answers was considered for a given inquiry skill, school, treatment class, or gender. The answers used in this report were based on the researcher's and research assistants' opinions and views concerning the representation of the responses. Learners' responses were regarded as displaying their level of competency in integrated science inquiry skills.

4.3.1.1 Learners' practical investigation responses on the ability to identify and control variables

In this integrated science inquiry skill, learners were required to identify the variables (independent, dependent and controlled variables) involved in the investigation. For controlled variables, learners were asked to name a minimum of three.

Practical investigation task 1

Tables 4.31(a) and (b) present some of the responses from individual and group treatment learners concerning the identification and control of variables in investigation task 1.

Table 4.31(a) Individual practical investigation responses on the ability to identify and control variables

Leaner code	Statement/Response
210YIF	Independent: Length of the string of the pendulum Dependent: The period Control: Mass of the object tied on the string (the mass must be the same); the size of the pendulum (the size of the pendulum must remain the same)
56SIF	Independent: Length Dependent: Time Control: Weight of the streme (sic); position of the stone release; number of swings; type of string; type of weight
58SIF	Independent: Length of the pendulum Dependent: Time (period) Control: Position of stone release; type of strings; type of weight; weight (mass) of the stone; same number of swings
137HIM	Independent: Length Dependent: Period Control: Weight; type of string/wool; position where it is performed

Table 4.31(b) Group practical investigation responses on the ability to identify and control variables

30SGF	Independent: Length Dependent: Periodic time Control: The weight (mass of the stone); the position of the stone release; same number of swings; the type of weight
138YGF	Independent :Length of the pendulum Dependent: Period of the pendulum Control: Mass; height (mass is dropped from); swinging angle
118HGF	Independent: Length of string Dependent: Period Control: Point at which the weight is released; number of strings

From the responses in table 4.31 (a) and (b), it is evident that learners in both classes were able to identify the independent, dependent and controlled variables. Most learners provided correct responses for the independent variable (length of the pendulum) and the dependent variable (period of the pendulum). Responses varied across the two groups, with weight and mass being widely reported.

Practical investigation task 2

This chemistry task required learners to mention one dependent and independent variable and two controlled variables as provided in tables 4.32 (a) and (b).

Table 4.32(a) Individual practical investigation responses on the ability to identify and control variables

108SIM	Independent: Concentration Dependent: Heat/ temperature Control: Volume of acid; room temperature; time to measure temperature
159HIF	Independent: Concentration Dependent: Temperature Control: Time for temperature change; volume of acid; type of acid (HCl)
253NIM	Independent: Concentration Dependent: Heat Control: Time (10minutes) and volume of acid
270NIF	Independent: Concentration Dependent: Temperature Control: Volume

Table 4.32(b) Group practical investigation responses on the ability to identify and control variables

98SGF	Independent: Heat produced Dependent: Concentration of the reactants Control: Volume of acid; room temperature
50SGM	Independent: Concentration of the reaction Dependent: Heat Control: Room temperature; time of the measure temperature; volume of HCl

149HGM	Independent: Concentration Dependent: Heat produced (temperature) Control: Type of acid; volume (amount of HCl; temperature at room temperature
312NGF	Independent: Concentration Dependent: Temperature change Control: Time; volume of acid

In tables 4.32(a) and (b) learners from both groups displayed the ability to identify variables in the chemistry section. The majority of learners responded correctly to the independent variable (concentration of HCl), dependent variable (amount of heat produced/ temperature change of the reaction contents) and controlled variables.

4.3.1.2 Learners practical investigation responses on the ability to hypothesise

This integrated science inquiry skill required learners to state the hypothesis of the practical investigative task.

Practical investigation task 1

In stating a hypothesis, learners were expected to provide a possible relationship between the dependent and independent variables as represented in tables 4.33 (a) and (b).

Table 4.33(a) Individual practical investigation responses on the ability to hypothesise

116HIM	If the length of the pendulum (string) is increased, the pendulum takes much time to complete the number of given swings
284NIF	If the length of the pendulum is increased, then the time will increase

Table 4.33(b) Group practical investigation responses on the ability to hypothesise

103SGF	The increase of length will increased the time of the pendulum
238YGF	If the length of the string decrease the period will increase
197YGF	If the mass increased the height, period and length will also increase
118HGF	If the length of the string is increased or decreased then the investigation of the period of the pendulum will be appropriate
289NGF	If the length of the pendulum is increase then the time will remain the same because the weight does not change

Nearly all learners from both groups provided correct hypotheses, as shown in table 4.33(a) and (b). Most learners were able to provide the relationship between the independent and dependent variables in the hypothesis.

Practical investigation task 2

The most probable relationship of the dependent and independent variables is mostly conveyed through the if … and then…statements, as in tables 4.34(a) and (b) in the chemistry practical investigation.

Table 4.34(a) Individual practical investigation responses on the ability to hypothesise

106SIF	If the concentration of one of the reactants is increase then the amount of heat produced will also increase
72SIM	If the concentration of reaction increase then the amount of heat will also increase
220YIM	The larger the concentration of HCl the higher the temperature
244YIF	The more the concentration of acid the less the heat produced
159HIF	If the concentration is increase then temperature increase
155HIM	If concentration is increased, then temperature will also increase
270NIF	If the amount of concentration is increased the temperature will also increase

Most learners provided correct hypotheses, as shown by the individual responses above (table 4.34(a)) and group responses below (table 4.34(b)).

Table 4.34(b) Group practical investigation responses on the ability to hypothesise

50SGM	If the concentration of one of the reacts increase then the amount of heat produced will able to increase
202YGF	The larger the concentration of HCl, the higher the temperature
176HGF	If the concentration is increased the heat produced also increases
312NGM	If you increase the concentration of one of the reactants then the rate of the reaction will also increase

4.3.1.3. Learners' practical investigation responses on the ability to operationally define variables

The expected answers on this integrated science process skill of operationally defining variables were based on learners' ability to describe how to measure a variable in an experiment.

Practical investigation task 1

The physics task data on the ability to define operationally is presented in tables 4.35(a) and (b). Learners were expected to respond to how the period of the pendulum would be measured at different lengths.

Table 4.35(a) Individual practical investigation responses on the ability to operationally define variables

47SIM	To measure the length of the pendulum using a ruler in cm and time using seconds with stop watch
210YIM	The length of the string will be measured by a ruler in centimetres The period will be measured by a stopwatch in seconds
116HIM	The length of a pendulum will be counted after every five (5) swings
137HIM	The time for 5 swings of different length of strings will be measured using a stopwatch
274NIM	I will measure the length of the pendulum with a ruler every time I increase it and make 5 swings and record them 3 times on a piece of paper

The learners' answers in table 4.35(a) showed that they understood what operationally defining variables was, and were able to operationally define the variable, the instrument to measure the quantity, and its unit. Most of the group treatment learners seemed to have mastered this skill better than the individual treatment learners, by providing definite answers as displayed in table 4.35(b).

Table 4.35(b) Group practical investigation responses on the ability to operationally define variables

238YGF	- A stopwatch to record the swing length of the pendulum - A protractor to measure the angle where the pendulum will swing from - A ruler to measure the length of the string
30SGF	The string of the pendulum will going to be measure by ruler using cm the swing it for five times within three time
173HGF	The length of the pendulum will be measured by a ruler using centimetres and count 10 swings using a stopwatch to record the time it takes
273NGM	I will use a ruler to measure the length of pendulum in centimetres and stop watch to measure time in second

Practical investigation task 2

The data in tables 4.36(a) and (b) show how learners defined operationally the way in which the temperature of the reaction between Zn and HCl would be measured in the chemistry task.

Table 4.36(a) Individual practical investigation responses on the ability to operationally define variables

72SIM	Measure the temperature change using a the memitre(sic) and measure the HCl concentration using $mol.dm^{-3}$
106SIF	Measure change using a thermometer and measure the HCl concentration using $mol.dm^{-3}$
244YIF	Acid inside the beaker will be measured by thermometer using mol/dm^{3} after every 5 minutes
220YIM	A thermometer will be use to measure the temperature changes before and after the reaction until there is no more rise in temperature
159HIF	Measure the temperature using thermometer (in °C) after 10 min, and measure concentration using in $mol.dm^{-3}$
280NIF	I'm going to measure the volume of acid using dm3 and the concentration will be measured in mol.dm-3 and the temperature measured by a thermometer every ten minutes

Table 4.36(b) Group practical investigation responses on the ability to operationally define variables

50SGM	Measure the temperature change using a thermometer and measure the HCl concentration using $mol.dm^{-3}$
197YGF	A thermometer will be used to measure the temperature changes before and after the reaction until there is no more rise in temperature
174HGF	I'm going to measure the acid concentration using $mol.dm^{-3}$. Measure the temperature change using thermometer
176HGF	I am going to measure using acid concentration in $mol.dm^{-3}$ and the change of temperature in $0^{0}C$ using thermometer
261NGF	Measure the concentration of the acid in $mol.dm^{-3}$ and measure the temperature using a thermometer in ^{0}C

Most learners from both treatment groups were able to define the variables (independent and dependent) to be measured in the chemistry task. Some learners gave only one variable and instrument or unit to measure, instead of providing both the instrument and the unit of measurement, as shown in tables 4.36(a) and (b).

4.3.1.4. Learners' practical investigation responses on the ability to design an experiment

This integrated science inquiry skill involved designing and conducting a controlled scientific test. Among other science inquiry skills, it included a plan of how learners were going to conduct the experiment and collect data.

Practical investigation task 1

The ability to design a pendulum experiment is demonstrated in the following data (tables 4.37(a) and (b)) to show how to determine the period of the pendulum at different lengths.

Table 4.37(a) Individual practical investigation responses on the ability to design an experiment

058SIF	- Apparatus: string, stone, ruler, stop watch, retort stand - You must tie up the stone with the string and tie both stone and string on the retort stand and use the ruler in (cm) to measure the length of the string, then use the stop watch to time taken for a (sic) strings to swings times in (seconds)
284NIF	I will use a wool and a little rock and tie the wool on something and start making swings, each and every after 5 swings, I will record the time taken and 3 times per cm

Table 4.37(b) Group practical investigation responses on the ability to design an experiment

238YGF	"I will make sure that the windows are closed so there are no elements affecting my pendulum; before I begin the investigation. Secondly, I will then measure the piece of 30cm string". "Thirdly, I will use a protector to measure exactly 90^0 of where to swing the pendulum from And finally, I will measure ten swings and the time it takes to complete them This is because it is easier to count the length of one swing".
273NGM	We used a ruler to measure the length of the pendulum, we first measured 5 cm (length) then used a stopwatch to read the outcome of the swings then increase the length to 10cm and increase it to 20cm (length) then we follow the same procedure to the end

From tables 4.37(a) and (b) it was evident that learners did not perform well in this science process skill. Neither group provided all the apparatus and materials needed to conduct the experiment to obtain the desired results. A handful of learners supplied a few steps on the experiment procedure to be followed.

Practical investigation task 2

The data below represents how learners designed an experiment to measure the amount of heat produced when Zn and HCl reacted.

Table 4.38(a) Individual practical investigation responses on the ability to design an experiment

159HIF	- Measure the 40ml of 1,0 mol.dm^{-3} of HCl - Measure the acid temperature and then put the zinc granule in the acid. - After 10min, recorded the temperature - Repeat steps 1-3 using 2.0 and 3.0 mol.dm^{-3} on the temperature
270NIF	Step 1:Put 40ml of acid into a beaker and make sure the amount is correct Step 2:Measure the temperature at start Step 3: Add a pellet of zinc into the beaker insert the thermometer in and leave it for 10 minutes Step 4: after ten minutes record the amount of temperature Step 5: repeat the same steps but changing the temperature and record the final temperatures after ten minutes three times then recorded the while information in a table

Table 4.38(b) Group practical investigation responses on the ability to design an experiment

98SGF	- Put 30ml of 1.0mol.dm^{-3} of HCl in a flask - Measure the temperature of the acid/Record the temperature - Put/Insert/Add a zinc granule and record temperature after ten minutes - Put 30ml of 2.0 mol.dm^{-3} of HCl in a flask, measure the temperature of the acid put a zinc granule & record temperature after ten minutes - Put 30ml of 3.0 mol.dm^{-3} of HCl in a flask, measure the temperature of the acid put a zinc granule & record temperature after ten minutes

Individual treatment learners showed poor understanding of what this science inquiry skill required, as shown in tables 4.37(a) and 4.38(a). Most learners from the group investigation showed improvement in designing an experiment as shown in table 4.38(b).

4.3.1.5. Learners' practical investigation responses on the ability to graph and interpret data

This integrated science inquiry skill required that learners make observations and record measurements (i.e. data) in an organised way. The learners should be able to draw graph(s) and make conclusions from the information obtained.

Practical investigation task 1

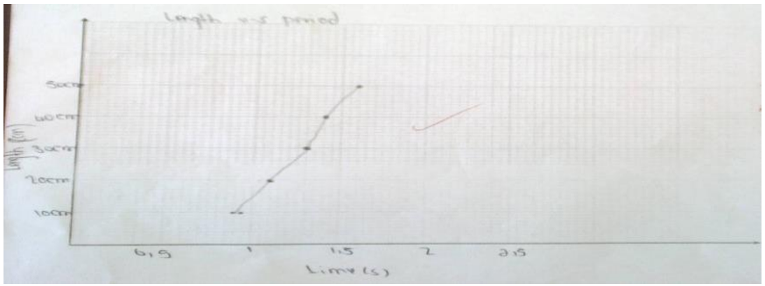
These data are representative individual responses on the ability to graph and interpret data from investigative task 1.

<u>Learner code: 210YIF</u>

Table 4.39(a) Recorded results of individual treatment learner 210YIF

Length	Period
10 cm	0.93 s
20 cm	1.11 s
30 cm	1.27 s
40 cm	1.38 s
50 cm	1.61 s

Figure 4.7 (a) Individual treatment learner (210YIF) graph



- Data interpretation

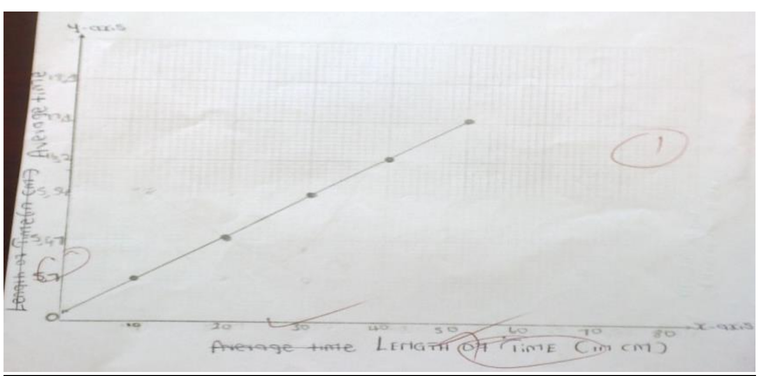
'From the information I got from the graph, I can say that the length is directly proportional to the period.'

<u>Learner code: 058SIF</u>

Table 4.39(b) Recorded results of individual treatment learner 058SIF

Length of the pendulum (in cm)	Time taken for 5 swings (in seconds)	Average time
10	1.5.5	5.7
	2. 5.7	
	3. 5.9	
20	1.5.5	5.47
	2.5.8	
	3. 5.11	
35	1.5.2	5.54
	2.5.5	
	3. 5.8	
40	1.5.2	16.2
	2.5.4	
	3. 5.6	
50	1.5.5	17.1
	2.5.7	
	3. 5.9	

Figure 4.7(b) Individual treatment learner (058SIF) graph



- Data interpretation

‘I have found out that the number’s [sic] in the average are increasing by step. As the length of the pendulum increases, the time also increases.’

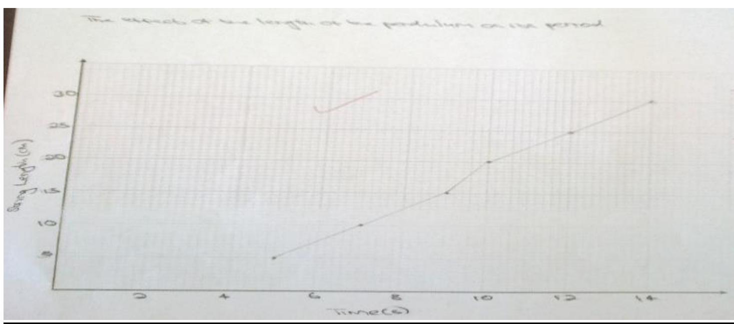
These data are representative of group practical investigation responses on the ability to graph and interpret data from investigative task 1.

<u>Learner code: 238YGF</u>

Table 4.40(a) Recorded results of group treatment learner 238YGF

String length	Number of swings	Time
30 cm	10	13 s
25 cm	10	12 s
20 cm	10	10 s
15 cm	10	9 s
10 cm	10	7 s
5 cm	10	5 s

Figure 4.8(a) Group treatment learner (238YGF) graph



- Data interpretation

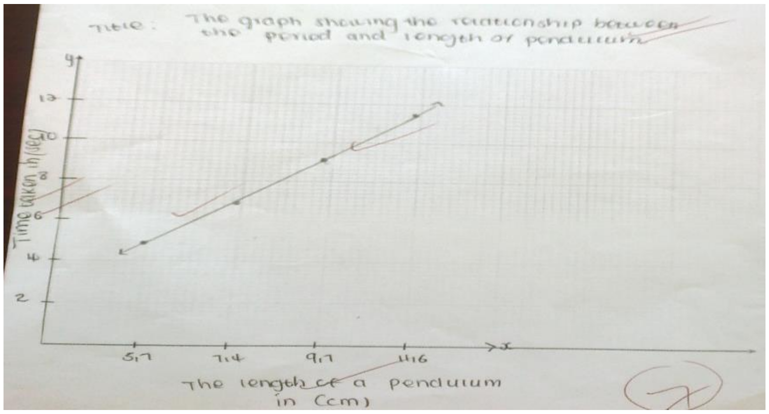
“The graph shows a general trend to exist when the string length is shorter than the time taken is less”.

<u>Learner code: 103SGF</u>

Table 4.40(b) Recorded results of group treatment learner 103SGF

Length of the pendulum in (cm)	Time taken (sec) for 5 swings.	Average time
7 cm	1. 5,5	5,7
	2. 5,7	
	3. 5,9	
14 cm	1. 7,2	7,4
	2. 7,4	
	3. 7,7	
21 cm	1. 9,5	9,7
	2. 9,7	
	3. 9,9	

Figure 4.8(b) Group treatment learner (103SGF) graph



- Data interpretation

> 'When the length of the string increases the longer it will swing in a way that it will take to much time an (sic) decrease in time will decrease.'

Most learners from both the individual and group practical investigations recorded their results in tabular form (tables 4.39(a), 4.39(b), 4.40(a) and 4.40(b) and variable units were also assigned. Few learners from both treatment classes failed to do repeated trials to determine the average per recorded results set. For both groups, graphing was excellent in most learners' reports, as reflected in the above graphs (figures 4.7(a), 4.7(b), 4.8(a) and 4.8(b)). Most data interpretations were mediocre, since they were about the trend of variables and in a few instances about proportionality.

Practical investigation task 2

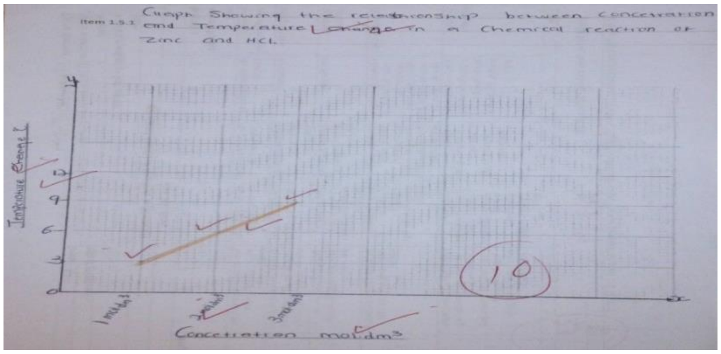
These data are representative individual responses on the ability to graph and interpret data from investigative task 2.

<u>Learner code: 270NIF</u>

Table 4.41(a) Recorded results of individual treatment learner 270NIF

Beaker	Concentration	Temperature		Temperature
		Start	End 10 min	Change
1	1.0 $mol.dm^3$	25^0	28^0	3^0
2	2.0 $mol.dm^3$	23^0	29^0	6^0
3	3.0 $mol.dm^3$	21^0	30^0	9^0

Figure 4.9(a) Individual treatment learner (270NIF) graph



- Data interpretation

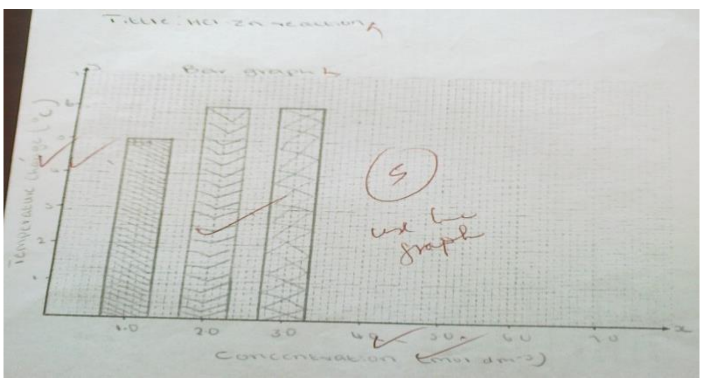
'When concentration increase the temperature change also increase'.

Learner code: 106SIF

Table 4.41(b) Recorded results of individual treatment learner 106SIF

Beaker	Concentration	Temperature		Temperature change
		Start	End	
1	1.0mol.dm^{-3}	22^0	27^0	5^0
2	2.0 mol.dm^{-3}	24^0	30^0	6^0
3	3.0 mol.dm^{-3}	26^0	32^0	6^0

Figure 4.9 (b) Individual treatment learner (106SIF) graph



- Data interpretation

'When the concentration increases, so does the temperature. They all increase as they go together.'

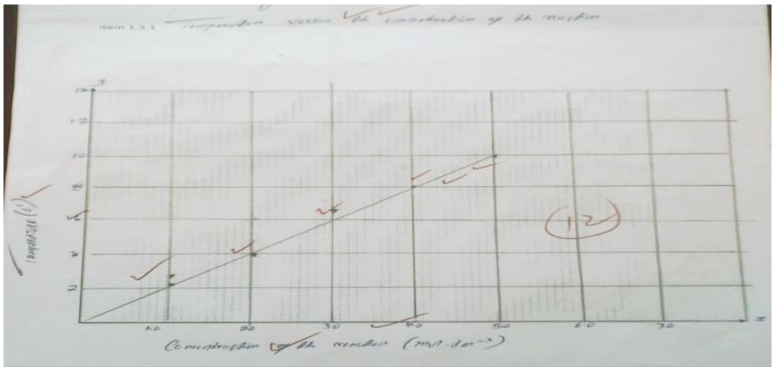
These data are representative group responses on the ability to graph and interpret data from investigative task 2.

<u>Learner code: 050SGM</u>

Table 4.42 Recorded results of group treatment learner 050SGM

Beakes(sic)	Temperature		Concentration	Temperature change
Beaker 1	30^0	34^0	1.0mol.dm^{-3}	4^0
	28^0	37^0	2.0 mol.dm^{-3}	9^0
	26^0	38^0	3.0 mol.dm^{-3}	12^0

Figure 4.10 Group treatment learner (050SGM) graph



- Data interpretation

> 'When the concentration of the reaction increase the temperature also increase. The temperature and concentration of the reaction are directly proportional.'

There was an improvement in recording results by most learners of group treatment in practical investigation task 2 reports, as shown in table 4.42. Individual treatment reports showed few learners recording all the variables and their units correctly, as shown in tables 4.41(a) and (b). Graphing for individual treatment learners was also a challenge, as most learners failed to label the axes correctly, as evident in graph scores (figures 4.7(b) and 4.9(b)). Most group treatment learners obtained high marks on graphing, as shown in figure 4.10 above. Result interpretation did not improve during practical investigation task 2 reports for either treatment class, as reported in practical investigation task 1 above.

4.3.2 Learners' views that could explain their performance on the integrated sciences process skills

The qualitative data in this section were used to answer research question 2: 'How can the development of these science inquiry skills by learners exposed to the two practical investigation learning methods be explained?'

Learners' views and opinions that could have accounted for their performance in assessments on science inquiry skills were obtained from the questionnaire responses. The questionnaires were administered after the intervention and the post-test. The responses were organised into six themes as discussed below.

4.3.2.1 Learners' interest in assigned practical investigation learning method

Learners who did practical investigations as individuals expressed their interest in doing practical investigations in this way as shown (table 4.43(a)).

Table 4.43(a) Individual treatment learners' interest in assigned practical investigation learning method

Learner code	Statement
179HIF	It was a great achievement to be able to do things in your own without a group participation it also gains self-confidence and independent
209YIF	I enjoy learning this investigation because it was my first time to do it and also going to the lab doing some experiment using thermometer, beaker and recording the result it was good for me
314NIF	I enjoyed working alone or I may say to be self independent. This is because a person at my age I need to learn and practice to relay on myself I even learned how to carry-out an experiment using different apparatus in different investigations
285NIF	What i enjoyed was that I had to do the experiment on my own. Without any1's help. That i had to also manage the time given. And that i had to know what to do when dealing with chemicals and other dangerous substances. So that I could not hurt ma self
044SIF	I enjoy because now I can identify independent variables, and dependent variables

Most learners in the group treatment showed enthusiasm at doing practical investigations as group as it generated a number of positive social behaviours among them, as expressed in table 4.43(b). Learners cited working together and interaction as positive ways of conducting practical investigations and learning.

Table 4.43(b) Group treatment learners' interest in assigned practical investigation learning method

231YGM	Enjoyed working with my group mates when thing were little/ a bit difficult for me I ask them and they will explain it till I understand it
238YGM	When you work with other people you learn more that you would have had if you worked alone because in a group you share ideas
310NGF	I enjoyed working as group and I enjoyed having company while we are doing experiment. Though I don't like to work with others I enjoyed the moment of this experiment so much
263NGM	Learning more but most importantly working in a group, hearing different opinions, hearing how people disagree or agree on different types of levels
295NGF	Doing practical's as a group, being corrected by a peer that what you are doing is wrong or right Learning that everything that we learn in chemistry is there because practical's were there to show that physical science it's not all about imaginary things but things we see

4.3.2.2 Learners' views on acquisition of science process skills after practical investigations

Most learners from both treatments revealed that after the practical investigations they had acquired new science inquiry skills, as supported by statements in tables 4.44(a) and (b). Science process skills that were mentioned frequently were measuring (especially temperature using a thermometer), and identifying variables.

Table 4.44(a) Individual treatment learners' views on acquisition of science process skills after practical investigations

219YIF	- Mixing concentration, checking the temperature of the concentration as it increased, know that temperature changes as the concentration is being changed - Seeing the correct degrees on the thermometer, the thermometer took a lot of time before it changed so it was disturbing me - I learnt how I can conduct investigation and experiment on myself and have more knowledge to make experiment on myself
314NIF	- I gained more skills of how to carry experiments, how to answer questions, handling apparatus in an admired way and also interpreting observation in form of graph and theory - Working alone was a bit challenging to me whereas I enjoyed it. At class we are used to work as a group but know I had to do things with my own without the help anyone - At first I never knew how experiments were taken or performed. But now I am a super star of collecting apparatus, observing, and interpreting investigation with required solutions
284NIF	- Measuring temperature, measuring the speed and using a stopwatch to determine rate, speed or temperature after a certain time - Some of the terms/concepts that were used in the test of integrated sciences process skills were difficult as I didn't know what they mean or I couldn't define them but lastly I ended up knowing their definitions - I learned that when your recording something that you have to record after a certain time immediately when your stopwatch show you that even allow it to pass with a minute because your will record things that are not correct

Table 4.44(b) Group treatment learners' views on acquisition of science process skills after practical investigations

202YGF	- Measuring temperature with a thermometer - Writing a report in the second investigation where I had to fill a table - I now know the difference between independent and dependent variable and I can write a report well without consulting a teacher for help
273NGM	- The skill of using stop watch, sharing ideas, drawing graphs, measuring substance and taking safety precaution before using things and using thermometer to measure temperature - Drawing graphs it was hard for me and to differentiate between independent variable and dependent variable - that do silly thing when the teacher is busy giving instructions on have use for the investigation so now I will listen everyone when is talking so that I may have many information and it will help me to observed what they want
078SGF	- Yes Like how to conduct the experiment. how to carry out the experiment - At first I didn't know how to find the investigative questions, hypothesis, aim, title etc in an practical investigation but now I know how to do it - Yes Because I've gained a lot of knowledge from the investigations we did. And I'm definitely going to use what I learnt in the investigations

4.3.2.3 Learners' views on challenges experienced during practical investigations

The individual treatment learners seemed to suggest that the challenges they experienced were data collection and recording, as reflected by the statements in table 4.45(a). In addition, some learners suggested that concepts associated with practical investigations were not initially familiar so that they struggled to understand.

Table 4.45(a) Individual treatment learners' views on challenges experienced during practical investigations

219YIF	- Seeing the correct degrees on the thermometer, the thermometer took a lot of time before it changed so it was disturbing me
280NIF	- Things that were difficult is that I did not know how I'm I going to record the temperature and how can we measure the volume of the acid
284NIF	- Some of the terms/concepts that were used in the test of integrated sciences process skills were difficult as I didn't know what they mean or I couldn't define them but lastly I ended up knowing their definitions

Most group treatment learners cited identifying variables and data collection as difficulties they first experienced when doing the practical investigations, as indicated in table 4.45(b). Others showed that drawing graphs and data interpretation were challenging.

Table 4.45(b) Group treatment learners' views on challenges experienced during practical investigations

291NGM	- To find the independent variable and dependent variable
273NGM	- The skill of using stop watch, sharing ideas, drawing graphs, measuring substance and taking safety precaution before using things and using thermometer to measure temperature - Drawing graphs it was hard for me and to differentiate between independent variable and dependent variable
292NGM	- How to identify independent and dependent variable. Identifying which apparatus are required for the investigation - Interpreting the finding of the investigation
062SGM	- Measuring the temperature was a bit of problem because sometimes the temperature remain the same

4.3.2.4 Learners' opinions on understanding practical investigations and science

Most learners from both treatments expressed good understanding of the relationship between practical investigations and their impact on science content knowledge. Most learners claimed to have gained a lot of science knowledge through practical investigations and experiments, as indicated in their views in tables 4.46(a) and (b). Most learners stated that after doing practical investigations, their 'science world' was opened, and that they acquired unfamiliar science terminology and concepts from in practical investigations and experiments. Some learners were unable to distinguish between practical investigations and science when responding to the questions.

Table 4.46(a) Individual treatment learners' opinions in understanding practical investigations and science

137HIM	- Yes, I now understand how experiments has to be done in the lab and how cautious a person has to be when conducting such experiments - No, except to thank you all the knowledge and understanding I gained from the process skills programme
219YIF	- Yes, It opened my mind and showed me a clearer view and how experiments are really done than to be explained for and getting it from a textbook and not getting a clearer vision - Yes, I got to understand how it is both in concept and skills I've got a brighter clearer skill and for concepts I am, I got better understanding than before
284NIF	- It helped me to understand science better as I learned many things and mostly about pendulums and many other things I didn't know before - Yes, There is a difference before the investigation there were much terms I didn't know but after the investigation I almost know those terms I didn't know before
002SIF	- Yes, Because I observe it clearly not for seeing it in a text book and I understand more things on those investigations - Yes, The term pendulum was difficult to me because it was my first time to hear it and it was difficult for me to define it

Table 4.46(b) Group treatment learners' opinions in understanding practical investigations and science

176HGF	- Yes, because chemical reactions and mechanical reactions were taking place whereby some were affected by independent/dependent - Yes, I now have gain skills of group working a working group in labs and also that steps or rules are not made to be broken or avoided that whatever you see in the investigation write it down
282NGF	vii) Because I thought or tell myself that science is not an easier subject to study, but after this investigation I realize that science just need your mind to be set up to give the information needed to answer or prove what you have to do or answer, first understand the given information ix) Before doing the investigation, there's a confusion of how to do this practical investigation the information is given but how to do it, after doing you get more knowledge and you understand what you were doing and what you were trying to find out through investigation

4.3.2.5 Learners' opinions regarding their performance on pre-test and post-test

Most individual treatment learners thought that they performed better in the post-test than in the pre-test. Reasons cited (table 4.47(a)) were better preparedness for the post-test and better understanding of practical investigations. Some learners thought that the performance might be the same, because the tests needed only a sense of thinking and reasoning.

Table 4.47(a) Individual treatment learners' opinions on performance between pre-test and post-test

137HIM	I think I will score much in the post-test than in the pre-test
219YIF	I think my both performances for both post-test and pre-test were excellent
185NIF	I think that on my pre-test I tried because it wrote it before I did an investigation But with the post-test I think I have improved because I had done an experiment, I had the idea on how to answer the questions
270NIF	My pre-test wasn't that good but the post test was very good and I think is because I've gained some knowledge from the first and then improved my performance
044SIF	I think at pre-test I didn't perform well so at my post-test I was going to perform well because now I was prepared

Most group treatment learners responded that they were optimistic that the post-test results would be better than the pre-test because in the pre-test there was a lot of guess work, but for the post-test there was better understanding of practical investigations, as shown in table 4.47(b) statements.

Table 4.47(b) Group treatment learners' opinions on performance between pre-test and post-test

247YGF	I have better and clearer answers for the second test than I did for the first one
282NGF	For the pre-test because was the first time and was not the best was just guessing, but for the post-test I think I did my best for my understanding about practical investigation
061SGF	I think I performed better in the post-test
095SGF	I think I did best on both of it because I've used all the knowledge I have and I have tried my best

4.3.2.6 Learners' perceptions on effectiveness of preferred learning method

Individual treatment learners were split over their preferred way of doing practical investigations. Some learners preferred to do practical investigations as individuals, and cited that the benefit of doing practical investigation individually was that it promoted independent academic work, which is likely to prepare them better for tertiary education (see table 4.48(a)). They pointed out that doing practical investigations individually promoted a hard-working attitude and that practical investigations should be conducted individually, since most examinations are written individually. In contrast, some learners preferred to conduct practical investigations in a group, and advanced the notion that in a group treatment learners were able to help each other when conducting investigations, hence learning from others.

Table 4.48(a) Individual treatment learners' perceptions on effectiveness of preferred learning method

181HIM	Group (preferred method) It is better to work with groups because members of the group have different ideas which you could make something out of it
118HIF	Individually (preferred method) One gets to know more about the benefit of doing alone and being independent in academic which I can refer to varsity *(university)* years as a student work hard alone and above all is to gain more understanding and knowledge without getting to look at what the next person is doing so individually promotes hard work
304NIF	Individually (preferred method) Because in a test you have to work alone. So you must start now to do things alone because in exam you won't be with a friend or a group work
284NIF	Individually (preferred method) It is better, as I like working alone and doing my own choices and my own knowledge and write what I know because when you're working with someone it might happen that you have different ideas and

	that makes you doing the wrong things
011SIF	In group (preferred method) Because you are able to help each other through thinking and conducting an investigation also make you work faster and easier. You also learn from other learners when you work as a group

Most of the group treatment learners preferred to work in groups. They viewed this as having certain benefits. First, learners are able to assist each other when help was sought. Second, group members developed better working skills with other people (see table 4.48(b)). Few group treatment learners preferred to do practical investigations as individuals.

Table 4.48(b) Group treatment learners' perceptions on effectiveness of assigned learning method

176HGF	Group(preferred method) In groups because it come to a point where you don't even have a clue on ideas of what is happening but people whom you are in the same group comes with the clue, you also think of another clue then the best and correct one comes to mind
290NGF	Group (preferred method) Because when you are working in a group with your group members you can help each other and it also helps you to know your friends better and also develop better working skills with other people
317NGM	Individually (preferred method) Working in a group is bad because you first have to argue with people to get the job done, there is always noise and a lot of mistakes, some other people will break stuff and spill stuff doing unnecessary things
282NGF	Group (preferred method) Working in a group is better, because the more you get confused, the more you ask your group member's the more you gain skills and knowledge in education especial in practical investigations
062SGM	Individually (preferred method) Working individually will help you to be have the ability to work independently without depending on other learners to do the work for you

4.4 CHAPTER SUMMARY

In summary, the results showed that no statistical significant difference in the development of integrated science inquiry skills by learners exposed to individual practical investigations or group practical investigations. The post-test results supported the null hypothesis that there is no significant difference in the development of the integrated science inquiry skills by learners exposed to individual and group practical investigations using TIPS. The qualitative data from practical reports showed that both classes did well in responding to questions related to the inquiry skills of identifying and controlling variables, hypothesising and operational design. Both individual and group treatment learners displayed optimism that they would perform better in the post-test than in the pre-test, according to responses to the questionnaire, even though the quantitative findings did not support an improved performance on the post-test of either the individual or the group treatment class.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 INTRODUCTION

This chapter presents a discussion of the research study results. It focuses on the assessment of the relative effectiveness of individual and group practical investigations in the development of integrated science inquiry skills. The assessment is based on learners' TIPS performance results, performance on practical investigations reports, and questionnaire responses.

5.2 INDIVIDUAL AND GROUP TREATMENT LEARNERS' PERFORMANCE ON TEST OF INTEGRATED SCIENCE PROCESS SKILLS

The discussion of learners' performance on TIPS consists of a comparison of their performances before and after the intervention.

5.2.1 Comparison of learner performance in integrated science inquiry skills before the intervention

This section comprises a discussion of the comparison of learners' overall and specific inquiry skills in the TIPS pre-test**.**

5.2.1.1 Comparison of the overall pre-test performance of individual and group practical investigation learners on integrated science process skills

The individual treatment learners' performance pre-test mean score did not differ significantly statistically from the group treatment learners' performance mean score. The results meant that the performance of learners who did practical investigations as individuals and those who worked in groups was the same statistically. Therefore, competence of the two groups in the assessed inquiry skills was similar prior to the learning treatment modality that was applied for the classes. The significance of this finding is that any differences observed after the treatment may be attributed to the different learning approaches that were used, if other variables are kept constant.

5.2.1.2 Comparison of pre-test performance of the individual and group treatment learners on specific integrated science inquiry skills

The inferential statistical results of the comparison of the performance of individual and group classes on the different integrated science process skills (ISPS) are summarised in table 5.1.

Table 5.1 Summary of comparative mean scores results of individual and group treatment learners on pre-test ISPS

ISPS	Skill	Independent sample t-test results (mean scores comparison)
ISPS1	Identify and control variables	No statistical significant difference between the mean scores
ISPS2	State hypotheses	No statistical significant difference between the mean scores
ISPS3	Operationally define variables	No statistical significant difference between the mean scores
ISPS4	Design experiments	No statistical significant difference between the mean scores
ISPS5	Draw graphs and interpret data	Mean scores differed significantly statistically

The competency level of both the individual and the group treatment classes in ISPS1 to ISPS4 was the same prior to the intervention. Random assignment of learners to the treatment classes might have contributed to the uniformity of the two treatment groups in their competency in ISPS. For ISPS5, however, the individual treatment learners achieved a better mean score than the group treatment learners. The inferential statistic results showed that this difference in mean scores was statistically significant. The observed difference might be the result of higher combined individual treatment scores of learners who performed better on questions based on graphing and interpreting data compared with the group treatment class scores.

5.2.2 Comparison of learner performance in integrated science inquiry skills after the intervention

The discussion on the performance of learners after the intervention is divided as follows: comparison of pre- and post-test performance of the individual treatment learners and the group treatment learners; comparison of overall learner performance on TIPS and on the specific ISPSs; comparison of performance on practical investigation reports scores; and learners' opinions about the development of integrated science inquiry skills and the use of individual and group learning methods.

5.2.2.1 Comparison of pre-test and post-test performance of individual and group treatment learners on test of integrated science process skills

In this sub-section, the discussion of comparison on TIPS starts with individual treatment learners' performances in pre- and post-tests, followed by those of group treatment learners in pre-and post-tests.

i) Comparison of pre-test and post-test performance of individual treatment learners on test of integrated science process skills

The individual treatment learners' post-test mean score of 12.8987 did not differ significantly statistically from that of the individual treatment learners' pre-test mean score of 12.8608 out of 30 marks. It affirms that conducting practical investigations individually did not make a huge improvement in mean score performance. Conducting practical investigations individually did not bring significant change in terms of the development of integrated science inquiry skills. The lack of significant performance differences by individual treatment learners after the intervention might imply that they were unable to apply the knowledge gained during practical investigations to the TIPS questions. This complies with the findings of Saat (2004), who indicated that at times learners were unable to apply the skills (controlling variables and formulating hypothesis) to another situation. The results, however, contrasted the individual treatment learners' views on performance on pre- and post-tests, which indicated that they were optimistic that they would perform better in the post-test, as shown in the extracts below (table 5.2).

Table 5.2 Individual treatment learners' views on pre-test and post-test performance

137HIM	I think I will score much in the post-test than in the pre-test
185NIF	I think that on my pre-test I tried because I wrote it before I did an investigation. But with the post-test I think I have improved because I had done an experiment, I had the idea on how to answer the questions

From the above statements, learners seemed hopeful of improving their post-test performance since they had done the hands-on practical investigations and were better prepared for the post-test assessment. The lack of significant difference between pre- and post-test performance might have been the result of inadequate practice in inquiry skills, since the intervention comprised only two practical activities. Providing more opportunities for inquiry activities has been identified by Dlamini (2008) as an effective way of promoting the development of science inquiry skills in learners. Learners in the current study could not be exposed to more inquiry activities because of limited resources and educational policies, which do not encourage the involvement of learners in research that extends over a long period.

ii) Comparison of pre-test and post-test performance of group treatment learners on test of integrated science process skills

The post-test mean score of 12.5167 of the group treatment learners did not differ significantly statistically from that of their pre-test mean score of 12.3417. The results showed that there was no significant improvement in performance in the group treatment class in post-test mean score compared with the pre-test mean score. Similar to the individual treatment class, learners who conducted practical investigations in small groups did not improve their performance during the post-test assessment.

Lack of performance improvement in the group treatment class was probably caused by poor learning processes, possibly the result of the group structure formation. Learners were randomly assigned to groups, and poor group structures might have formed. Poorly formed group structures might have caused inadequate cooperation. Tosun and Taskesenligil (2013) noted that a problem of inadequate cooperation in a group is that instead of struggling to solve inquiry activities as a group, members might prefer individual study. The benefits of group work activities under such conditions are not achieved, hence learner performance is not easily improved. The problem of inadequate exposure to practical activities could have affected the post-test performance of the group class as well. Like individual treatment learners, group treatment learners were optimistic about positive improvement on post-test performance as reflected in table 5.3 by the following statements:

Table 5.3 Group treatment learners' views on pre-test and post-test performance

247YGF	I have better and clearer answers for the second test than I did for the first one
061SGF	I think I performed better in the post-test

Despite the lack of statistical significance difference in the pre- and post-test mean scores, a closer look at descriptive statistical results (tables 4.33 and 4.34) showed that the mean scores of post-test compared with the pre-test performance for individual treatment learners decreased on ISPS1 (identifying and controlling variables) and ISPS2 (defining hypothesis), whereas ISPS1 and ISPS2 for group practical investigations had improved. The decreased learner performance mean scores may suggest that the paper and pencil test (TIPS) used to measure the inquiry skills could not measure learner's competency in these skills directly, since these skills are usually more evident in practical tasks. In addition, this result may mean that the development of integrated science inquiry skills and the application of these skills in assessment situations might not be correlated (Saat (2004). This inference could be deduced from the next extract (table 5.4) from learners' declaration of improved inquiry skills after the intervention.

Table 5.4 Learner's view on the development of ISPS after practical investigations

314NIF	- I gained more skills of how to carry experiments, how to answer questions, handling apparatus in an admired way and also interpreting observation in form of graph and theory - At first I never knew how experiments were took or performed. But now I am a super star of collecting apparatus, observing, and interpreting investigation with required solutions

From these statements, the inference was that individual treatment learners felt that their inquiry skills improved after the intervention. Nonetheless, based on the empirical results of ISPS1 and ISPS2 in the pre and post-tests, this study could suggest that for improved performance on the development of integrated science inquiry skills ISPS1 and ISPS2, learners should be taught through group practical investigations. In addition, the results from the comparison of the pre- and post-test performances of individual and group treatment classes suggest that either individual or group practical investigations may be used to develop the integrated science inquiry skills of ISPS3, ISPS4 and ISPS5, as there were no statistical significant differences in the pre- and post-test mean scores of the individual and group treatment learners.

5.2.2.2 Comparison of the overall post-test performance of individual and group treatment learners on test of integrated science process skills

The individual treatment learners' performance post-test mean score of 12.90 did not statistically differ significantly from that of group treatment learners' performance mean score of 12.52. The results indicate that neither the individual nor the group practical investigation method was more effective than the other in developing integrated science inquiry skills in learners. In other words, the competencies of individual practical investigations and of group practical investigation classes in integrated science inquiry skills were similar after the intervention. The null hypothesis that there is no significant difference in the development of integrated science inquiry skills by learners exposed to individual and group practical investigations was supported, that (H_0: $\mu_{\text{individual treatment performance}} = \mu_{\text{group treatment performance}}$). The null hypothesis was based on investigative question 1: Is there any difference in the integrated science inquiry skills developed by learners exposed to individual and those exposed to group (cooperative) practical investigations?

The results might possibly be because learners are used to a teacher-centred strategy in learning practical investigation skills. Learners from both treatment classes might have struggled during the transition from teacher-centred learning to inquiry learning, which probably led to minimum participation in their classes, hence the lack of significant improvement in learners' performance in the post-test by both treatment classes. This assumption is cited by Tosun and Taskesenligil (2013), who contend that learners that are used to conventional instruction have difficulty in adapting to new instructional practices. In addition, the limited exposure of learners in both treatment groups to inquiry activities, as stated in the previous section, could equally have affected their performance in the post-test (Tosun & Taskesenligil, 2013).

The lack of significant differences in the development of inquiry skills by individual and group treatment learners exposed to individual and group investigation learning suggest that either individual or group practical investigations could be used to develop science inquiry skills in learners. This finding is particularly important when one considers the lack of resources in South African rural schools, which forces some educators to resort to group practical investigations.

5.2.2.3 Comparison of post-test performance of the individual and group treatment learners on specific integrated science inquiry skills

A comparison was made of the performance of individual and group treatment classes on specific integrated science inquiry skills. The independent sample t-test results of the comparison are summarised in table 5.2 below.

Table 5.5 Summary of t-test results for the comparison of the performances of individual and group treatment learners on specific ISPS's in the post-test

ISPS	Skill	Independent t-test results (mean scores comparison)
ISPS1	Identify and control variables	No statistical significant difference between the mean scores
ISPS2	State hypotheses	No statistical significant difference between the mean scores
ISPS3	Operationally define variables	No statistical significant difference between the mean scores
ISPS4	Design experiments	No statistical significant difference between the mean scores
ISPS5	Draw graphs and interpret data	No statistical significant difference between the mean scores

There were no statistical significant differences between the mean scores of individual and group treatment learners of ISPS1, ISPS2, ISPS3, ISPS4 and ISPS5. The lack of significant difference on post-test mean scores of these specific inquiry skills between the two treatment classes may be attributed to learners not being afforded an opportunity to do scientific inquiry on their own. For ISPS1, both treatment groups' learners might have been aware that variables are obtainable from the problem statement of the practical investigation, hence learners performed similarly. Similar findings on ISPS1 about group treatment class performance were reported by Rapudi (2004) in his research study on 'the effect of cooperative learning on the development of learners' science process skills' that there was no significant effect on the development of the learners' science process skill of controlling variables by the group investigation method of cooperative learning.

On ISPS2 (stating a hypothesis), the post-test mean scores performance showed no significant difference between the two classes. The possible explanation is that hypothesis formulation depends on the ability to identify variables (ISPS1). It was probable that both treatment group treatment learners realised that to formulate the hypothesis from variables (as suggested by Germann & Aram, 1996), the hypothesis is derived from the causal (independent) variable in the first part of the sentence and the responding (dependent) variable is the second part. Similar performances by the two treatment groups on ISPS1 might have contributed to no significant difference on ISPS2 performance between the two groups.

The mean scores performance on ISPS3 (defining variables operationally) for both treatment groups showed that there was no statistical significant difference between them. This skill is dependent on learners having mastered ISPS1 because they have to provide the quantities and instruments that measure the changes of dependent variables with respect to manipulated quantities of independent variables. That there was no significant difference performance on ISPS3 by both treatment groups might be attributed to the ISPS1 outcome.

The present study results showed that the individual treatment class mean score 4.14 was higher than the group treatment class of 4.03 on ISPS4 (designing experiments) as reflected in table 4.25 and 4.26, but without any statistical significant difference. Contrary to this study's results on ISPS4, Rapudi (2004) found that the group investigation method positively influenced the development of learners' science process skills of experimenting ($p = 0.005 < 0.05$). This suggests that when several practical investigations are conducted using group practical investigation, this may enhance the development of the skill of designing an experiment.

For ISPS5 (drawing graphs and interpreting data) performance mean scores of both treatment groups were 1 out of 3 after the post-test. This represents a poor performance. This weak performance might have contributed to the lack of statistical significant difference between mean scores of individual and group treatment classes. Group performance contradicted Rapudi's (2004) findings. In his study Rapudi (2004) found that there was a positive influence on the development of the skill of graphing through cooperative learning. The contrast between this study's findings and those of Rapudi could be because the current study combined graph and data interpretation in one integrated science inquiry skill, whereas in the study by Rapudi graphing alone constituted one skill. The explanation is supported by the earlier findings by Beaumont-Walters and Soyibo (2001), who reported that learners performed fairly well in interpreting data that demanded extracting information from graphs, and were less successful in identifying supporting evidence. It is noted that in the pre-test, the individual treatment learners performed better than the group treatment learners; while the post-test results did not show a significant difference between the two groups regarding ISPS 5. This could imply that the performance of the group treatment learners improved more than that of the individual treatment learners for this particular skill.

Interpreting data seemed to be a challenge for both treatment groups, which was evident from practical investigation reports submitted by learners. Their interpretation of results consisted mostly one sentence showing the relationship between the dependent and independent variables, as represented in these practical report extracts in tables 5.6 a) and b).

Table 5.6 a) Individual treatment learners' practical report extracts on data interpretation

210YIF	From the information I got from the graph, I can say that the length is directly proportional to the period
270NIF	When concentration increase the temperature change also increase

Table 5.6 b) Group treatment learners' practical report extracts on data interpretation

238YGF	"The graph shows a general trend to exist when the string length is shorter than the time taken is less".
050SGM	When the concentration of the reaction increase the temperature also increase. The temperature and concentration of the reaction are directly proportional

Most learners reported similarly. It seemed that learners were unable to interpret the data that they had tabulated and graphed so well. Poor interpretation of data is possibly the results of poor teaching strategy and lack of practice in conducting practical investigations at lower school grades in the four schools.

5.3 COMPARISON OF LEARNERS' PERFORMANCE ON PRACTICAL INVESTIGATION REPORTS

This section answers investigative question 1, which stated: 'Is there any difference in the integrated science inquiry skills developed by learners exposed to individual and those exposed to group (cooperative) investigations?', and question 2: How can performance in these science inquiry skills by learners exposed to the two learning methods be explained?

Analysis of learners' performance on practical investigation reports based on an independent sample t-test showed that group treatment learners' mean score did not statistically differ significantly from that of the individual treatment learners. These results support the null hypothesis that there was no significant difference between the individual and group treatment learners in developing integrated science inquiry skills.

The practical investigation reports' findings on the development of science inquiry skills are consonant with the findings from the TIPS test, which showed non-significant differences in the mean scores. The absence of significant difference in the mean scores of learners exposed to different learning methods during practical investigations was also observed from a study by Rauf, Rasul, Mansor, Othman and Lyndon (2013). The practical investigation reports in the current study provided the following findings.

- ***Identifying and controlling variables***

Learners from both groups were able to identify the independent and dependent variables without much difficulty.

- ***Stating a hypothesis***

Learners exposed to different practical investigation methods were very good at providing hypotheses for the two investigations. Learners provided the relationship between the dependent and independent variables when stating the hypotheses.

- ***Operational definitions***

Most learners performed well as it relies more on the skills of identifying and controlling variables and stating a hypothesis. This skill is important because it directs the course of the investigation to obtain the desired results. Learners in the current study provided the quantities and their measuring units to show that they understood the inquiry skill as derived from the dependent and independent variables.

- ***Experimental design***

The results showed that most learners did not develop this skill. From the practical report, it was evident that both individual and group treatment learners' were unable to outline the plan and materials/apparatus needed to conduct both of the practical investigation tasks. In addition, this skill required that learners ran repeated trials to find solutions to the problems. Data measurements and recording were done, but few learners conducted 'fair tests' to ensure that the results were reliable.

- ***Graphing and interpreting data***

From practical reports, it was evident that most learners from group treatment had acquired the skill of graphing, but performed poorly in interpreting data. Group treatment learners were able to draw graphs, and label the dependent and independent axis. However, graph plotting lacked the concept of the 'line of best fit'. Data interpretation was the most challenging part to most learners in both treatment groups. In consequence, it seems that learners from both groups needed to be provided with opportunities to practise the skill of making inferences and conclusion from data and information. It also appears that learners from both treatment groups experienced challenges with expressing themselves in a second language.

In summary, on evaluating the responses, it emerged that in all five inquiry skills, there was improvement between practical investigation task 1 responses and task 2, except for graphing and interpreting data. On the graphing part, learners showed improvement, but on interpretation of data there was no performance improvement for learners from either group.

The subsequent improvement in the performance results on practical reports from the initial or previous to the following ones was an indication that learners started developing the scientific inquiry skills as they were exposed to more practical activities. The development of scientific inquiry skills occurs through certain stages as suggested by Saat (2004) in his report on the acquisition of integrated science process skills in a web-based learning environment.

5.4 EXPLANATION OF THE QUANTITATIVE FINDINGS

The quantitative findings from the TIPS and practical reports revealed, first, that learners from both the individual and the group classes did not significantly improve their integrated science inquiry skills after the intervention; and, second, the performances of learners exposed to individual and group practical investigations were not statistically different.

Based on the questionnaire analyses, it seemed that most learners who participated in the research study were conducting scientific inquiry investigations or being in the laboratory performing investigations for the first time. Representative data (table 5.7) from each of the four participating schools' learners reinforces the notion that most learners were doing practical investigations for the first time:

Table 5.7 Learners' experiences during practical investigations

Learner code	Statement
209YIF	I enjoy to learn this investigation because it was my first time to do it and also going to the lab doing some experiment using thermometer, beaker and recording the result it was good for me
285NIF	Because before the investigation I knew nothing about practical investigations. But now im glad that I know lot of things. Including the laboratory rules and other stuff. And how to behave when in a lab and that you can do investigations alone without partners
078SGF	At first I didn't know how to find the investigative questions, hypothesis, aim, title etc in an practical investigation but now I know how to do it
118HIF	Before I had no idea on how to write reports, set up an experiments, understand some terms and identify the controlled, independent and dependent variables so the investigations helped me understand more

As a result, the instructions and the science process skills being developed might have constituted a large information load that needed to be processed for understanding to occur (Pollock, Chandler & Sweller, 2002). The development of integrated science inquiry skills in practical investigation settings by novice learners is assumed to follow the cognitive load theory by Haslam and Hamilton (2010). This theory deals with the cognitive processing system of new information in mental memory. The mental memory consists of two processing system memories, namely a working memory and a long-term memory. Working memory is where conscious processing of new information occurs and has a limited capacity in processing new information and in the lifespan of information retention (Sweller, 2005). When new information is loaded in working memory by learners with little prior knowledge, such as in practical investigations, it could be easily overloaded if the quantity and complexity of the information exceed working memory capacity (i.e. cognitive overload) (Haslam & Hamilton (2010). If cognitive overload happens, understanding and learning are negatively affected.

On the other hand, long-term memory appears to have limitless capacity to store information. Information is stored in schemas in hierarchically organised domain-specific elements linked together in working memory (Sweller, 2005). To understand new information for instructions and materials, existing knowledge must be retrieved from schemas of long-term memory (Haslam & Hamilton, 2010) .When people move from being novice to expert within a field, there is an increase in both the richness of the information and how fast and automatically the information is retrieved (Sweller, 1994) from long-term memory.

The cognitive load theory seemed to explain what happened to learners during practical investigations when faced with scientific inquiry and processes on new scientific investigative information and concepts. The new concepts and inquiry skills processes could have been stored in the working memory and then in the long-term memory as they did the second practical investigations, reports writing and eventually taking TIPS post-test.

Similarly, the cognitive load theory reflected the findings by Saat (2004) about the three phases of learning, namely recognition, familiarisation and automation. In the phase of recognition, learners displayed the ability to recognise the skill or concept encountered probably from the initial interaction (Saat, 2004), but not internalised the meaning and had not acquired the skills during practical investigation and report processing. This phase possibly occurred in this study when learners were engaged in practical investigation task 1 especially on ISPS3, ISPS4 and ISPS5 since they are mostly not treated in South African Revised National Curriculum Statement (RNCS) GET curriculum.

The second phase is when learners' were aware of the meaning of concept or skill but not fully internalised or developed it. In this study, it is assumed that the second phase happened during the processes of practical investigation task 2.The final phase of automation, involved stage where learners had internalised the material and concepts involved during the scientific research process and had internalised the meanings and fully developed the inquiry skills. As the phase of automation needs repetition (practice) to be internalised, it was probable that in this study most learners did not achieve that level because of the less number of practical investigation tasks offered. The three phases are steps that new information in learners' cognitive capacity passes through such that learning and inquiry skills development should be attained.

5.5 LEARNERS' VIEWS THAT COULD ACCOUNT FOR PERFORMANCE ON INTEGRATED SCIENCE PROCESS SKILLS

5.5.1 Views on interest in assigned practical investigation learning method

Both individual and group classes expressed interest in the learning methods they were exposed to. But this was not translated into improved performance in either of the learning methods. The quantitative results of this study showed that there is no significant difference between individual and group practical investigation learning methods in the development of integrated science inquiry skills. This discrepancy in learners' declared interest and their performance in assessments has been observed by other researchers. For example, Kazeni (2012) in her study on 'Teaching approaches in enhancing learners' performance in life sciences' reported that learners' interest and enjoyment in the study of science did not translate into improved achievement.

With regard to the group practical investigation, it was not surprising for learners to be interested and to enjoy working in small groups. According to Hart, Mulhall, Berry, Loughran and Gunstone (2000) most science inquiry tasks become interesting when learners work in groups. However, the impact of group work in this study did not yield improved performance, similar to individual practical investigations. It appears that interest does not result in enhanced performance, regardless of the method used to conduct practical investigations.

5.5.2 Views on acquisition of science process skills after practical investigations

Learners from the individual and group treatment classes claimed that they had developed integrated science process skills during the intervention. However, the quantitative results are contrary to this view. The contradiction could be assumed on the premise that learners view practical investigations as being both affective and effective (Abrahams & Reiss, 2012) in terms of developing science inquiry skills. In this regard, learners in this study could have been interested in the practical investigations and assumed that their interest is translated into development of inquiry skills. However, since they were not sufficiently exposed to practical investigations, they could not fully develop the inquiry skills, as suggested by Dlamini (2008). Other studies confirm that science inquiry skills are not improved when laboratories are not utilized efficiently (Feyzioglu, 2009; Hofstein & Naaman, 2007).

The results of the current study correspond with those of Musasia, Abacha and Biyoyo (2012), who reported that after practical investigations learners were confident about having developed science inquiry skills. Musasia et al. (2012) concluded that learners picked up science inquiry skills and information more quickly when doing practical investigations than when being lectured to, hence the improved confidence level.

In the current study therefore, learners' positive perception of their acquisition of science process skills after practical investigations could not explain their performance in assessments to test their competence in science inquiry skills. Factors such as learners' inability to transfer developed inquiry skills to written assessments (Saat, 2004) and limited exposure to practical investigations (Dlamini, 2008)) might account for this discrepancy.

5.5.3 Views on challenges experienced during practical investigations

Individual and group practical investigations' learners expressed the same difficulties in data collection, especially using thermometers. In addition, most individual treatment learners had challenges on scientific concepts, while the group treatment learners were challenged when drawing graphs and interpreting data. Contrary to the data collection and graphing problems expressed by individual and group treatment learners, respectively, findings from the practical reports painted a different picture, as both groups obtained relatively fair scores.

Despite the challenges presented by most learners in both the treatment groups, many studies have demonstrated that integrated science inquiry skills are developed mainly through experimentation and practical investigation (Chabalengula, Mumba & Mbewe, 2012; Salim, Puteh & Daud, 2010; Shi, Power & Klymkowsky, 2011; Coil, Wenderoth, Cunningham & Dirks, 2010).

5.5.4 Opinions on understanding practical investigations and science

The two classes of learners expressed good understanding of practical investigations. This theme was included in this study to find out whether learners' understanding of practical investigations would improve their comprehension of science content and their attitude towards science. This theme was premised on assertions by several researchers that there is a link between practical investigations and enhancement of science content. For instance, Toplis (2012) suggested that practical investigations play a central role in developing learners' in-depth understanding of science content during secondary schooling. Gibson and Chase (2000) reported that short-term studies showed that learners who use science inquiry methods have an improved attitude towards science. Amunga, Musasia and Musera (2011) indicated that understanding science process skills makes learners take science seriously.

Because of the limited duration of the present study, sufficient data could not be gathered to fully expand the impact of this theme. However, it is clear from learners' views that they perceived their involvement in practical investigations as having improved their understanding of science and their attitudes towards the study of science, as is evident from the following learners' quotations in table 5.8.

Table 5.8 Learners' opinions on understanding practical investigations and science

282NGF	vii) Because I thought or tell myself that science is not an easier subject to study, but after this investigation I realize that science just need your mind to be set up to give the information needed to answer or prove what you have to do or answer, first understand the given information. ix) Before doing the investigation, there's a confusion of how to do this practical investigation the information is given but how to do it, after doing you get more knowledge and you understand what you were doing and what you were trying to find out through investigation
219YIF	- Yes, It opened my mind and showed me a clearer view and how experiments are really done than to be explained for and getting it from a textbook and not getting a clearer vision -Yes, I got to understand how it is both in concept and skills. I've got a brighter clearer skill and for concepts I am, I got better understanding than before
284NIF	- It helped me to understand science better as I learned many things and mostly about pendulums and many other things I didn't know before

	- Yes, There is a difference before the investigation there were much terms I didn't know but after the investigation I almost know those terms I didn't know before

This perceived improvement in science, especially in inquiry skills, could be seen from their performance in practical reports, although their performance on TIPS did not show much improvement. Further studies are required to validate this finding.

5.5.5 Opinions regarding performance in pre-test and post-test

Both classes of learners were optimistic that they would perform better in the post-test, but the quantitative findings showed no significant improvement between learner performance in the pre- and post-test. Post-test improvement was dependent on the holistic development of the five integrated science inquiry skills after the two practical investigations tasks. The development of science inquiry skills, as stated earlier, occurs in stages (Saat, 2004). Mastery of these requires an extended treatment. This resonates with Padilla's (1990) findings that experimenting abilities need to be practised over time.

The lack of significant improvement in learner performance from pre-test to post-test has been reported in studies on science inquiry skills. For example, Rainford (1997) found that Jamaican Grade 7's performance on three basic science process skills (observing, classifying and inferring) barely increased from the pre-test to post-test, after they had been taught the ROSE Grade 7 science curriculum content. In addition, a study by Rapudi (2004) on the science inquiry skills of observation, controlling variables, graphing and experimentation revealed that pre- and post-test performance was significant in graphing and experimentation, but not significant in observation and controlling variables in the jigsaw and group investigation methods over two schools. The findings of the current study are therefore not peculiar to studies dealing with the development of science inquiry skills regarding no significant difference between pre- and post-test performance.

5.5.6 Perceptions on effectiveness of preferred learning method

Individual treatment learners were split in terms of their preference for doing practical investigations as individuals and as groups, while most of the group treatment learners preferred to work in groups. The overall quantitative study findings showed that there is no significant difference between the effectiveness of individual and group practical investigations in developing integrated science inquiry skills. Some individual treatment learners who preferred to be in group investigations might have been enticed by group activity benefits as highlighted under section 2.7

(social constructivism). Moreover, Musasia et al. (2012) suggest that group treatment learners make their own individual conclusions in practical investigations.

In the present study, group treatment learners did not encounter difficulties such as those reported by Tosun and Taskesenligil (2013), in which 58 per cent of the experimental group complained about inadequate cooperation within groups and about group structure. Therefore, in this study, the lack of significant differences in the effectiveness of the learning methods in the development of integrated science inquiry skills could have been caused by other factors, such as limited exposure to practical investigations.

5.6 CHAPTER SUMMARY

The study results showed no significant differences in the development of integrated science inquiry skills by learners exposed to individual and group investigations, and between the pre and post-test performance. The cognitive theories by Haslam and Hamilton (2010) and Saat (2004), especially the limited exposure to practical investigations, were deemed relevant for explaining the findings from this study.

Although the researcher was not able to find any studies with which the findings of the study could be compared directly, comparisons were made based on studies involving integrated science inquiry skills in which elements of the current study were identified. Such studies were conducted internationally (Germann & Aram, 1996; Harlen, 1999; Beaumont-Walters & Soyibo, 2001; Lord, 2001; Saat, 2004; Rauf et al., 2013) and in South Africa (Rambuda & Fraser, 2004; Rapudi, 2004; Dlamini, 2008). These studies focused on acquisition and learner performance, in relation to other skills such as attitude or logical thinking. The findings from the current study draw many parallel with these studies.

The findings from this study have parallel outcomes, consistent with the study by Beaumont-Walters and Soyibo (2001) based on the Smart Schools initiative, which promotes smart teaching founded on constructivist practice and self-directed learning to develop science process skills. Beaumont-Walters and Soyibo (2001) found that the null hypothesis was supported, which is similar to that of this study. Both studies used constructivism as a framework on the development of ISPS by secondary school learners.

The results of the comparison of the performances of individual and group treatment learners on the development of integrated science inquiry skills provided a response to the primary research question: 'How do group practical investigations compare with individual practical investigations in learners' development of integrated science inquiry skills?' Learners who conducted individual and group investigations performed similarly during the post-test TIPS. This implied that none of the teaching and learning modalities to which the two classes were exposed was more effective in developing the integrated science inquiry skills of identifying and controlling variables, stating a hypothesis, operational definitions, experimental design, and graphing and data interpretation.

The qualitative findings were based on the representative statements of both individual and group treatment learners. The organised themes of views on interest in assigned learning method, acquisition of science process skills, challenges experienced during practical investigations, and opinions regarding pre- and post-test performance explained some empirical quantitative results.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 INTRODUCTION

This chapter provides a summary of the study, conclusions, and evaluation of the methodology. Its possible contribution, limitations, recommendations, and suggestions for further research are presented.

6.2 SUMMARY OF THE STUDY

The primary aim of the study was to compare the relative effectiveness of individual and group practical investigations in the development of integrated science inquiry skills. The study was prompted by the emphasis on the promotion of learners' development of science process skills through prescribed and recommended practical investigations and experiments in CAPS. The development of integrated science inquiry skills occurs during practical activities using various instructional methods including individual and group practical investigations. In this study, the researcher wanted to find out whether there was a statistical significant difference in the development of science inquiry skills between learners conducting practical investigations using individual and group practical investigations methods. The five integrated science inquiry skills investigated were identifying and controlling variables, stating hypothesis, operational definitions, experimental design, and graphing and interpreting data. In addition, the researcher explored the possible factors that could influence the development of these skills by learners conducting practical investigations individually or as a group.

Data were collected from four schools and involved 319 learners. The instruments used to collect data were TIPS, practical investigation reports and questionnaires. The TIPS instrument was used for pre-test and post-test, while the practical reports and questionnaires were used after the intervention. The learners' mean scores in the post-test for the individual and group practical investigation classes were compared to determine the statistical significance of the differences. Practical investigation report mean scores were also used to determine whether there was a statistically significant difference between the performances of the two treatment groups. Practical report responses were used to assess the performances of the two classes in inquiry skills.

Questionnaire responses were used qualitatively to determine the factors that could have influenced the development of these integrated science inquiry skills.

The quantitative results showed that there is no statistical significant difference between the performances of individual and group practical investigation classes in the development of integrated science inquiry skills. However, there were differences in the two treatment groups' performance on the five integrated science inquiry skills.

Practical investigation reports elicited information on learners' development of the integrated science inquiry skills. These reports addressed research question 1 and 2. Comparison of the mean scores of the individual and group investigation classes showed that there is no statistical significant difference between the practical investigation reports mean scores of individual and group treatment classes on the development of integrated science inquiry skills. Nonetheless, the responses suggest that learners from both groups were fairly competent in the skills of identifying and controlling variables, hypothesising and operational defining variables. The skills of designing experiments and data interpretation appeared to be a challenge to most learners in both treatment groups.

The views and opinions of learners from individual and group treatment classes provided data for investigative research question 2, which explored the possible reasons for the quantitative findings. Learners from both classes expressed interest in the practical investigation learning methods. The individual treatment classes showed preference for both individual and group practical investigations, while most group treatment learners preferred group investigation practical work. Most learners from both treatment classes were optimistic about improving their post-test performance, contrary to the quantitative findings.

6.3 CONCLUSION

In order to answer investigative question 1, a comparison of the performance of individual and group classes using the independent sample t-test showed that individual practical investigation learners' performance on post-test mean (mean = 12.90, standard deviation = 4.779) at ($t = 0.641$, $df = 116.132$, two-tailed $p = 0.523$) did not differ significantly statistically from group practical investigation learners' performance mean (mean = 12.52, standard deviation = 4.001). These results confirmed the null hypothesis that there was no significant difference between the individual and group practical investigation learners' performance on the development of integrated science inquiry skills; H_0: $\mu_{\text{individual treatment performance}} = \mu_{\text{group treatment performance}}$. These results were supported by a comparison of learners' practical investigation report mean scores using the Independent sample t-test, in which there was no significant difference in the performance of the two classes either. The study results showed that the development of integrated science inquiry skills during practical investigations was similar for both classes of learners. The limited exposure of learners to practical investigations could account for this result.

After the second investigation task, qualitative analysis of the learners' practical investigation reports showed that there were improvements in learners' performance in specific integrated science inquiry skills. Both groups showed an improved performance in the skills of identifying and controlling variables, stating hypothesis, operational definitions and experimental design from practical reports on task 1 to practical investigation reports on task 2. On the integrated science inquiry skill of graphing and interpreting data, most learners from the group practical investigations performed better on graphing, but did poorly on interpreting data. The majority of learners from both classes showed that it was their first experience of conducting practical investigations in a science laboratory, and expressed interest in doing so. Most learners expressed their anticipation of improved performance in post-test scores, according to the responses derived from the questionnaire.

6.4 EVALUATION OF THE METHODOLOGY OF THE STUDY

This section presents an evaluation of the methodology of the study. It provides an opportunity to assess the challenges that might have contributed to the research study's limitations. The evaluation focuses on the number of participants, the instruments, namely TIPS and a research questionnaire, and data analysis procedures.

6.4.1 Number of participants

In this study, 319 learners participated, which was a fairly large number. Increasing the participants to more than the stated number would have increased the financial budget for the research, which was already stretched. However, a much bigger sample might have provided more reliable results. Generalising the study result might therefore be affected by the number of participants in the study. The limitation of generalising findings from a small sample should be considered when applying the findings of this study to a larger sample (Kazeni, 2012). Random sampling, involving a selected sampling interval, was used to assign learners to individual or group practical investigation classes. The sampling method increased internal validity and comparability of the two groups, and minimised the influence of extraneous factors. The ratio used for the sampling interval was 1 : 3 (individual treatment learner : group treatment learners). This method of assigning participants to groups appears to be a good way of enhancing comparability.

6.4.2 Instruments

Although TIPS was used for both pre-test and post-test assessment of integrated science inquiry skills, learner's competency in these skills was not measured directly. Direct assessment of competency in the integrated science inquiry skills during an open-inquiry practical activity would have consumed a lot of time, which is unrealistic for a study of this nature. The assessment of inquiry skills using TIPS was considered sufficient, even though learners could not display the required inquiry skill(s) more explicitly.

Learners' views about the development of inquiry skills and the learning methods used to perform practical investigations were obtained through a questionnaire. Interviews could have probed the learners' answers and provided an in-depth understanding of their responses. Face-to face interviews, in which facial expression and body language provide useful information about the emotional status of the participant, were not used, because this could have limited the sampling size drastically. In addition, some learners could have been fearful of being interviewed, especially if they were not using their mother tongue.

6.4.3 Data analysis procedure

In this study, quantitative data were analysed using the inferential statistics of independent sample t-test using SPSS package. It is a powerful tool in comparing mean scores of two groups for statistical significant differences. For the tool to be used without violating the normality assumption, which causes type I error, the scores to be compared must assume normality. Individual and group treatment pre-test scores, post-test scores and practical investigations reports scores were tested for normality before descriptive and inferential statistics were analysed. The normality test for individual and group practical investigations scores was conducted using the Shapiro-Wilcox test of SPSS. Both treatment groups' scores were found to be relatively normally distributed, and therefore type I error was not committed in the statistical analyses.

Researcher bias is a factor that needs attention when selecting representative responses from qualitative results. Representative questionnaire responses provided by learners about their views of the development of inquiry skills and effective practical investigation learning methods were selected. Representative practical investigation report answers for the five integrated science inquiry skills were also selected. These responses were assumed to generalise the views of individuals and group members under the various themes. This was done to avoid transcribing a large volume of texts, which would be time consuming. To reduce researcher bias in selecting representative responses, two assistant researchers provided second opinions about them. Selected representative responses in which consensus were reached constituted the questionnaire results in this study.

Finally, the study data were collected from the Grade 11 learners doing physical sciences in four schools in Mopani Education District in Limpopo; hence the generalisation of the results is limited to this educational district.

6.5 POSSIBLE CONTRIBUTION OF THE STUDY TO ACADEMIC KNOWLEDGE

The findings of the study may shed light on how to conduct practical investigations. The current study revealed the following:

- There was no significant difference in the development of inquiry skills by learners exposed to individual and group practical investigations. This finding suggests that individual and group practical investigations could be effectively used to develop integrated science inquiry skills. The finding is particularly important when one considers the limited resources in most South African rural schools, which force teachers to resort to group practical activities.

- The skills of graphing and interpreting data were not well developed by learners exposed to both individual and group practical activities. This finding suggests that emphasis should be placed on the development of graphing and data interpretation skills when teaching integrated science inquiry skills through practical investigations, regardless of the investigation method.

- There was no significant difference in the performance of learners from the two groups in the pre-test and post-test. A possible explanation is limited exposure to practical investigations. The implication is that the development of integrated science inquiry skills might require prolonged exposure to practical investigations.

6.6 RECOMMENDATIONS

CAPS advocates for the development of science inquiry skills in the general and further education training bands in natural sciences subjects in South African schools. Based on the findings of this study and in line with this advocacy, these recommendations are advanced:

1 Neither the individual nor the group investigations method was found to be more effective in the development of the five integrated science inquiry skills of identify and control variables (ISPS1), stating hypothesis (ISPS2), operationally defining variables (ISPS3), designing experiments (ISPS4) and drawing graphs and interpreting data (ISPS5). Therefore, either practical investigation method of teaching and learning may be employed during practical investigations. However, the researcher suggests that for development of ISPS1 and ISPS2, preference should be given to groups since learners in the group treatment improved their mean scores compared with the declined individual treatment class after the post-test.

2 Given the finding of this study regarding the effectiveness of individual and group investigations, educators should be informed of the possibility of using either approach in the development of integrated science inquiry skills, during in-service training, especially in rural schools, which are under-resourced.

3 The research findings showed insignificant differences between learners' pre- and post-test performances for both treatment groups. One explanation could be the limited exposure of learners to practical activities. Educators should be encouraged to expose learners to more practical investigations in order to sufficiently develop integrated science inquiry skills.

6.7 SUGGESTIONS FOR FURTHER RESEARCH

The findings of this study suggest that these research studies should be considered in future in the field of science education:

- Research study on finding out how individual and group practical investigations compare in the development of integrated science inquiry skills with respect to gender, location of the school and learners' formal reasoning abilities in the South African context.

- Research based on investigating the effects of computer-assisted learning and logical thinking on the development of integrated science inquiry skills between individual and group practical investigation learners in rural schools.

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LIST OF APPENDICES

Appendix A: The test instrument- test of integrated science process skills

THE TEST INSTRUMENT

TEST OF INTEGRATED SCIENCE PROCESS SKILLS

DURATION: 50 minutes

INSTRUCTIONS:

1. **VERY IMPORTANT!!!!!!!!!!!!**

   DO NOT WRITE ANYTHING ON THE QUESTION PAPER.

2. **ANSWER ALL THE QUESTIONS ON THE ANSWER GRID PROVIDED, BY PUTTING A CROSS [X] ON THE LETTER OF YOUR CHOICE.**

3. **PLEASE DO NOT GIVE MORE THAN ONE ANSWER PER QUESTION.**

1. A learner wanted to know whether an increase in the amount of vitamins given to children results in increased growth.

How can the learner measure how fast the children will grow?

A. By counting the number of words the children can say at a given age.
B. By weighing the amount of vitamins given to the children.
C. By measuring the movements of the children.
D. By weighing the children every week.

2. Nomsa wanted to know which of the three types of soil (clay, sandy and loamy), would be best for growing beans. She planted bean seedlings in three pots of the same size, but having different soil types. The pots were placed near a sunny window after pouring the same amount of water in them. The bean plants were examined at the end of ten days. Differences in their growth were recorded.

Which factor do you think made a difference in the growth rates of the bean seedlings?

A. The amount of sunlight available.
B. The type of soil used.
C. The temperature of the surroundings.
D. The amount of chlorophyll present.

3. A lady grows roses as a hobby. She has six red rose plants and six white rose plants. A friend told her that rose plants produce more flowers when they receive morning sunlight. She reasoned that when rose plants receive morning sunlight instead of afternoon sunlight, they produce more flowers.

Which plan should she choose to test her friend's idea?

A. Set all her rose plants in the morning sun. Count the number of roses produced by each plant. Do this for a period of four months. Then find the average number of roses produced by each kind of rose plant.
B. Set all her rose plants in the morning sunlight for four months. Count the number of flowers produced during this time. Then set all the rose plants in the afternoon sunlight for four months. Count the number of flowers produced during this time.
C. Set three white rose plants in the morning sunlight and the other three white rose plants in the afternoon sun. Count the number of flowers produced by each white rose plant for four months.
D. Set three red and three white rose plants in the morning sunlight, and three red and three white rose plants in the afternoon sunlight. Count the number of rose flowers produced by each rose plant for four months.

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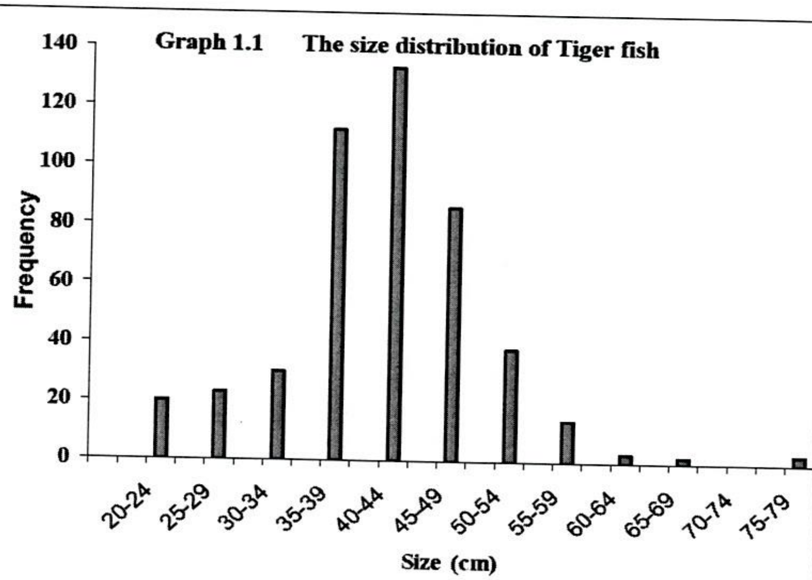
Questions 4 and 5 refer to the graph below.

The fishery department wants to know the average size of Tiger fish in Tzaneen dam, so that they could prevent over-fishing. They carry out an investigation, and the results of the investigation are presented in the graph below.

Graph 1.1 The size distribution of Tiger fish



4. What is the most common size range of Tiger fish found in Tzaneen dam

   A. 75 – 79 cm.
   B. 40 – 44 cm.
   C. 20 – 79 cm.
   D. 45 – 49 cm.

5. In which size range would you find the longest Tiger fish?

   A. 75 – 79 cm.
   B. 40 – 44 cm.
   C. 20 – 79 cm.
   D. 35 – 49 cm.

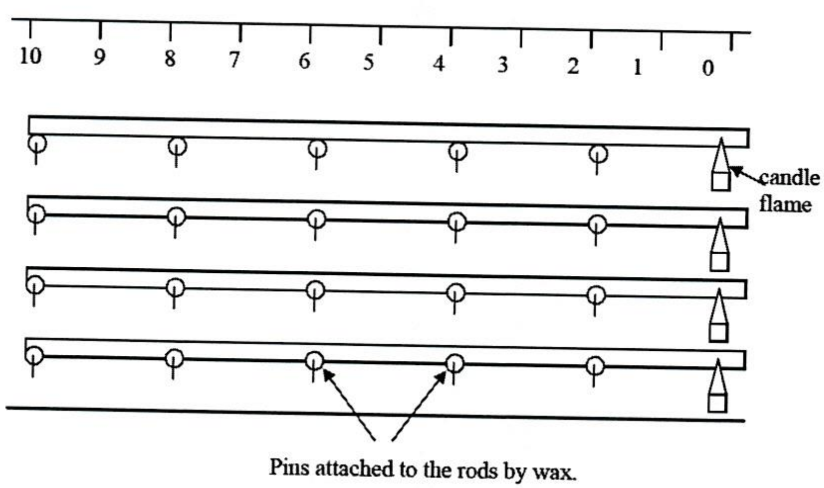
6. Mpho wants to know what determines the time it takes for water to boil. He pours the same amount of water into four containers of different sizes, made of clay, steel, aluminium and copper. He applies the same amount of heat to the containers and measures the time it takes the water in each container to boil.

Which one of the following could affect the time it takes for water to boil in this investigation?

A. The shape of the container and the amount water used.
B. The amount of water in the container and the amount of heat used.
C. The size and type of the container used.
D. The type of container and the amount of heat used.

7. A teacher wants to find out how quickly different types of material conduct heat. He uses four rods with the same length and diameter but made of different types of material. He attaches identical pins to the rods using wax, at regular intervals as shown in the diagram below. All the rods were heated on one end at the same time, using candle flames. After two minutes, the pins that fell from each rod were counted.

Diagram 1.1



How is the speed (rate) of heat conduction by the various rods measured in this study?

A. By determining the rod, which conducted heat faster when heated.
B. By counting the number of pins that fall from each rod after 2 minutes.
C. By counting the number of minutes taken for each pin to fall from the rod.
D. By using wax to measure the rate of heat conduction.

8. A farmer wants to increase the amount of mealies he produces. He decides to study the factors that affect the amount of mealies produced.

Which of the following ideas could he test?

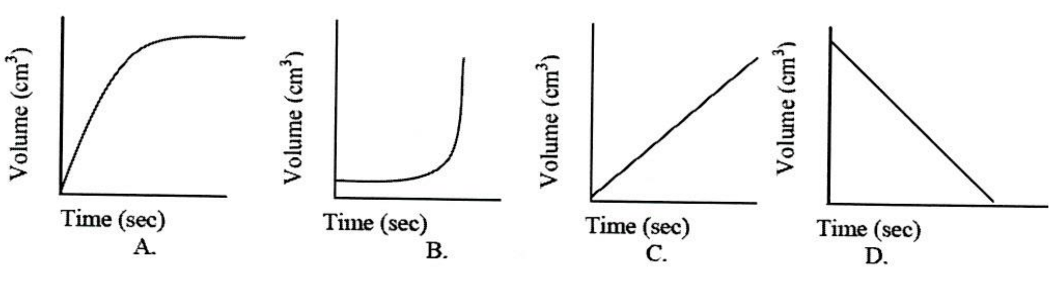
A. The greater the amount of mealies produced, the greater the profit for the year.
B. The greater the amount of fertilizer used, the more the amount of mealies produced.
C. The greater the amount of rainfall, the more effective the fertilizer used will be.
D. The greater the amount of mealies produced, the cheaper the cost of mealies.

9. Sandile carried out an investigation in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen produced from the reaction, every second. The results are shown below.

Time (seconds)	0	1	2	3	4	5	6	7
Volume (cm^3)	0	14	23	31	38	40	40	40

Table 1.1. Shows the volume of hydrogen produced per second.

Which of the following graphs show these results correctly?



10. A science teacher wanted to find out the effect of exercise on pulse rate. She asked each of three groups of learners to do some push-ups over a given period of time, and then measure their pulse rates: one group did the push-ups for one minute; the second group for two minutes; the third group for three minutes and then a fourth group did not do any push-ups at all.

How is pulse rate measured in this investigation?

A. By counting the number of push-ups in one minute.
B. By counting the number of pulses in one minute.
C. By counting the number of push-ups done by each group.
D. By counting the number of pulses per group.

11 Five different hosepipes are used to pump diesel from a tank. The same pump is used for each hosepipe. The following table shows the results of an investigation that was done on the amount of diesel pumped from each hosepipe.

Size (diameter) of hosepipe (mm)	Amount of diesel pumped per minute (litres)
8	1
13	2
20	4
26	7
31	12

Table 1.2. Shows the amount of diesel pumped per minute.

Which of the following statements describes the effect of the size of the hosepipe on the amount of diesel pumped per minute?

A. The larger the diameter of the hosepipe, the more the amount of diesel pumped.
B. The more the amount of diesel pumped, the more the time used to pump it.
C. The smaller the diameter of the hosepipe, the higher the speed at which the diesel is pumped.
D. The diameter of the hosepipe has an effect on the amount of diesel pumped.

12. Doctors noticed that if certain bacteria were injected into a mouse, it developed certain symptoms and died. When the cells of the mouse were examined under the microscope, it was seen that the bacteria did not spread through the body of the mouse, but remained at the area of infection. It was therefore thought that the death is not caused by the bacteria but by certain toxic chemicals produced by them.

Which of the statements below provides a possible explanation for the cause of death of the mouse?

A. The mouse was killed by the cells that were removed from it to be examined under the microscope.
B. Bacteria did not spread through the body of the mouse but remained at the site of infection.
C. The toxic chemical produced by the bacteria killed the mouse.
D. The mouse was killed by developing certain symptoms.

13. Thembi thinks that the more the air pressure in a soccer ball, the further it moves when kicked. To investigate this idea, he uses several soccer balls and an air pump with a pressure gauge. How should Thembi test his idea?

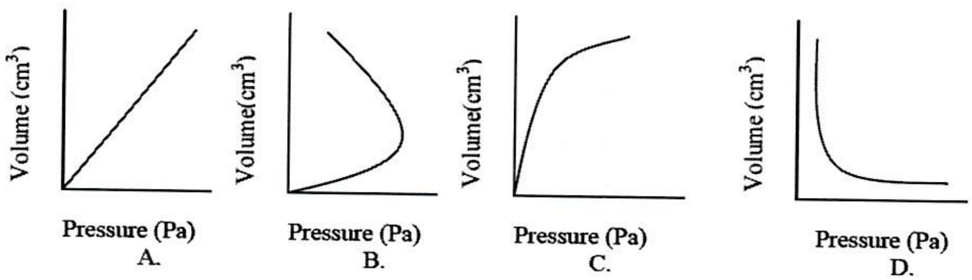
A. Kick the soccer balls with different amounts of force from the same point.
B. Kick the soccer balls having different air pressure from the same point.
C. Kick the soccer balls having the same air pressure at different angles on the ground.
D. Kick the soccer balls having different air pressure from different points on the ground.

14. A science class wanted to investigate the effect of pressure on volume, using balloons. They performed an experiment in which they changed the pressure on a balloon and measured its volume. The results of the experiment are given in the table below.

Pressure on balloon (Pa)	Volume of the balloon (cm^3)
0.35	980
0.70	400
1.03	320
1.40	220
1.72	180

Table 1.3. Shows the relationship between the pressure on a balloon and its volume.

Which of the following graphs represents the above data correctly?



15. A motorist wants to find out if a car uses more fuel when it is driven at high speed. What is the best way of doing this investigation?

A. Ask several drivers how much fuel they use in one hour, when they drive fast, and find the average amount of fuel used per hour.
B. Use his own car to drive several times at different speeds, and he should record the amount of fuel used each time.
C. He must drive his car at high speed, for a week, and then drive it at low speed for another week, and record the amount of fuel used in each case.
D. Ask several drivers to drive different cars covering the same distance many times, at different speeds, and record the amount of fuel used for each trip.

16. A learner observed that anthills (termite moulds) in a certain nature reserve tend to lean towards the west, instead of being straight. In this area, the wind blows towards the direction in which the anthills lean.

Which of the following statements can be tested to determine what causes the anthills to lean towards the west, in this nature reserve?

A. Anthills are made by termites.
B. Anthills lean in the direction in which the wind blows.
C. Anthills lean towards the west to avoid the sun and the rain.
D. The distribution of anthills depends on the direction of the wind.

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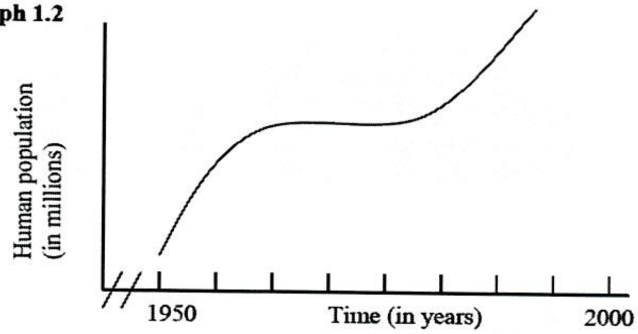
17. The graph below shows the changes in human population from the year 1950 to 2000.

Graph 1.2



Which of the following statements best describes the graph?

- A. The human population increases as the number of years increase.
- B. The human population first increases, then it reduces and increases again as the number of years increase.
- C. The human population first increases, then it remains the same and increases again as the number of years increase.
- D. The human population first increases then it remains the same as the number of years increase.

18. Mulai wants to find out the amount of water contained in meat, cucumber, cabbage and maize grains. She finely chopped each of the foods and carefully measured 10 grams of each. She then put each food in a dish and left all the dishes in an oven set at 100°C. After every 30 minutes interval, she measured the mass of each food, until the mass of the food did not change in two consecutive measurements. She then determined the amount of water contained in each of the foods.

How is the amount of water contained in each food measured in this experiment?

- A. By heating the samples at a temperature of 100°C and evaporating the water.
- B. By measuring the mass of the foods every 30 minutes and determining the final mass.
- C. By finely chopping each food and measuring 10 grams of it, at the beginning of the investigation.
- D. By finding the difference between the original and the final mass of each food.

19. In a radio advertisement, it is claimed that Surf produces more foam than other types of powdered soap. Chudwa wanted to confirm this claim. He put the same amount of water in four basins, and added 1 cup of a different type of powdered soap (including surf) to each basin. He vigorously stirred the water in each basin, and observed the one that produced more foam.

Which of the factors below is **NOT** likely to affect the production of foam by powdered soap?

A. The amount of time used to stir the water.
B. The amount of stirring done.
C. The type of basin used.
D. The type of powered soap used.

20 Monde noticed that the steel wool that she uses to clean her pots rusts quickly if exposed to air after using it. She also noticed that it takes a longer time for it to rust if it is left in water. She wondered whether it is the water or the air that causes the wet exposed steel wool to rust.

Which of the following statements could be tested to answer Monde's concern?

A. Steel wool cleans pots better if it is exposed to air.
B. Steel wool takes a longer time to rust if it is left in water.
C. Water is necessary for steel wool to rust.
D. Oxygen can react with steel wool.

21. A science teacher wants to demonstrate the lifting ability of magnets to his learners. He uses many magnets of different sizes and shapes. He weighs the amount of iron filings picked by each magnet.

How is the lifting ability of magnets defined in this investigation?

A. The weight of the iron filings picked up by the magnets.
B. The size of the magnet used.
C. The weight of the magnet used to pick up the iron filings.
D. The shape of the magnet used.

22. Thabo wanted to show his friend that the size of a container affects the rate of water loss, when water is boiled. He poured the same amount of water in containers of different sizes but made of the same material. He applied the same amount of heat to all the containers. After 30 minutes, he measured the amount of water remaining in each container.

How was the rate of water loss measured in this investigation?

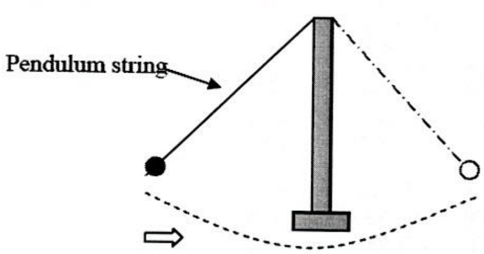
A. By measuring the amount of water in each container after heating it.
B. By using different sizes of the containers to boil the water for 30 minutes.
C. By determining the time taken for the water to boil in each of the containers.
D. By determining the difference between the initial and the final amounts of water, in a given time.

23. A school gardener cuts grass from 7 different football fields. Each week, he cuts a different field. The grass is usually taller in some fields than in others. He makes some guesses about why the height of the grass is different. Which of the following is a suitable testable explanation for the difference in the height of grass.

A. The fields that receive more water have longer grass.
B. Fields that have shorter grass are more suitable for playing football.
C. The more stones there are in the field, the more difficult it is to cut the grass.
D. The fields that absorb more carbon dioxide have longer grass.

24. James wanted to know the relationship between the length of a pendulum string and the time it takes for a pendulum to make a complete swing. He adjusted the pendulum string to different lengths and recorded the time it took the pendulum to make a complete swing.

Diagram 1.2 A pendulum.



He obtained the following results from an investigation.

Length of string (cm)	80.0	100.0	120.0	140.0	160.0	180.0
Time taken (seconds)	1.80	2.02	2.21	2.39	2.55	2.71

Table 1.4. The relationship between the lengths of a pendulum string and the time the pendulum takes to make a complete swing.

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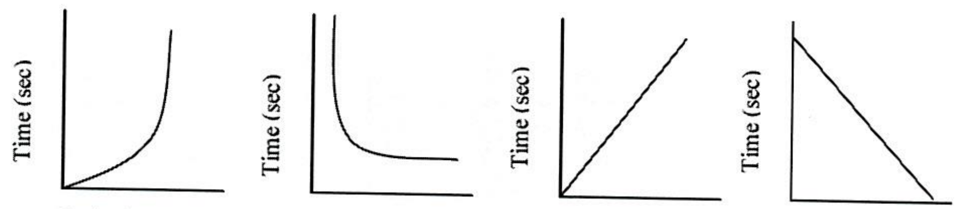
Which of the following graphs represent the above information correctly?



String length (cm) String length (cm) String length (cm) String length (cm)
A. B. C. D.

25. A farmer raises chickens in cages. He noticed that some chickens lay more eggs than others. Another farmer tells him that, the amount of food and water given to chicken, and the weight of chicken, affect the number of eggs they lay.

Which of the following is **NOT** likely to be a factor that affects the number of eggs laid by the chickens?

A. The size of the cage where the eggs are laid.
B. The weight of the chickens.
C. The amount of food given to the chickens.
D. The amount of water given to the chickens.

26. A science class wanted to test the factors that might affect plant height. They felt that the following is a list of factors that could be tested: the amount of light, amount of moisture, soil type, and change in temperature.

Which of the statements below could be tested to determine the factor that might affect plant height?

A. An increase in temperature will cause an increase in plant height.
B. An increase in sunlight will cause a decrease in plant moisture.
C. A plant left in light will be greener than one left in the dark.
D. A plant in sand soil loses more water than one in clay soil.

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27. A Biology teacher wanted to show her class the relationship between light intensity and the rate of plant growth. She carried out an investigation and got the following results.

Light intensity (Candela)	**Plant growth rate (cm)**
250	2
800	5
1000	9
1200	11
1800	12
2000	15
2400	13
2800	10
3100	5

Table 1.5. Shows the relationship between light intensity and the growth rate of a plant.

Which of the following statements correctly describes what these results show?

A. As light intensity increases, plant growth also increases.
B. As plant growth increases, light intensity decreases.
C. As plant growth increases, light intensity increases then decreases.
D. As light intensity increases, plant growth increases then decreases.

Questions 28, 29 and 30 refer to the investigation below.

Thabiso is worried about how the cold winter will affect the growth of his tomatoes. He decided to investigate the effect of temperature on the growth rate of tomato plants. He planted tomato seedlings in four identical pots with the same type of soil and the same amount of water. The pots were put in different glass boxes with different temperatures: One at 0°C, the other at 10°C, and another at room temperature and the fourth at 50°C. The growth rates of the tomato plants were recorded at the end of 14 days.

28. What effect does the differences in temperature have in this investigation?

A. The difference in the seasons.
B. The difference in the amount of water used.
C. The difference in growth rates of the tomato plants.
D. The difference in the types of soil used in the different pots.

29. The factor(s) that were being investigated in the above experiment are:

A. Change in temperature and the type of soil used.
B. Change in temperature and the growth rate of the tomato plants.
C. The growth rate of tomato plants and the amount of water used.
D. The type of soil used and the growth rate of the tomato plants.

30. Which of the following factors were kept constant in this investigation?

A. The time and growth rate of tomato plant.
B. The growth rate of tomato plants and the amount of water used.
C. The type of soil and the amount of water used.
D. The temperature and type of soil used.

Appendix B: The test instrument marking memorandum

SCORING KEY FOR THE DEVELOPED TEST INSTRUMENT

Item #	Correct option	Item #	Correct option	Item #	Correct option
1	D	11	A	21	A
2	B	12	C	22	D
3	D	13	B	23	A
4	D	14	D	24	C
5	A	15	D	25	A
6	C	16	C	26	A
7	B	17	C	27	D
8	B	18	D	28	C
9	A	19	C	29	B
10	B	20	C	30	C

Appendix C$_1$: Practical investigation task 1

Practical investigation 1: Pendulum (Physics)

PHYSICAL SCIENCES

GRADE 11

PRACTICAL INVESTIGATION 1

Duration: 90 min **Marks: 40**

A story is told of Galileo, that he was once attending a service in the cathedral at Pisa when his attention was distracted by the swinging of a lamp which was suspended from the roof by a long chain. Using the beats of his pulse as a clock, he noticed that the time of swing of the lamp remained constant even when the oscillations were dying away. The lamp was behaving as a pendulum. For a pendulum, the periodic time depends on the length of the pendulum.

Plan, design and conduct an investigation to find out whether the changing of length of the pendulum has an effect on the period of a pendulum.

Guidelines for planning & conducting practical investigation

1. **Phase 1 Planning**
   - Identify a problem
   - Variables limited to more than one controlled
   - Investigative question
   - Hypothesis
2. **Phase 2 Designing**
   - Sketch
   - Procedure
   - Tables for recording data
   - Decide on the type of graph(s)
3. **Phase 3 Conducting**
   - Conduct the experiment
   - Complete tables
   - Draw graphs
   - Interpret results
   - Draw conclusion

Adapted from Limpopo Education Department: Curriculum section, Practical investigation 1 grade 12, 2012

Appendix C$_2$: Practical investigation task 2

Practical investigation 2: HCl-Zn reaction (Chemistry)

PHYSICAL SCIENCES

GRADE 11

PRACTICAL INVESTIGATION 2

Duration: 90 min **Marks: 40**

It is an undeniable fact that the more you increase the concentration of one of the reactants the rate of the reaction will also increase. That is, the higher the concentration the faster the reaction. It is of learners' interest to investigate whether the amount of heat produced will depend on an increase in the concentration of one of the reactants.

Plan, design and conduct an investigation to find out whether the amount of heat (gas) produced will depend on an increase on the concentration of HCl when HCl reacts with an excess Zn.

Guidance / Hint

You may investigate either the amount of heat produced or the amount of gas produced (make a choice from the start to avoid confusion and write your topic accordingly).

Guidelines for planning & conducting practical investigation

1. **Phase 1 Planning**
   - Identify a problem
   - Variables limited to more than one controlled
   - Investigative question
   - Hypothesis
2. **Phase 2 Designing**
   - Sketch
   - Procedure
   - Tables for recording data
   - Decide on the type of graph(s)
3. **Phase 3 Conducting**
   - Conduct the experiment
   - Complete tables
   - Draw graphs
   - Interpret results
   - Draw conclusion

Adapted from Limpopo Education Department: Curriculum section, Practical investigation 2 grade 12, 2012

Appendix D: Practical investigation report writing format

REPORT WRITING FORMAT FOR PRACTICAL INVESTIGATION

NAME OF A LEARNER:…..

NAME OF SCHOOL:…………………………………………………………………....

GRADE………………………………………………… DATE…………………………….. **Total Mark: 40**

Title of investigation: (This must appear on the cover page of the report).

1.0 IDENTIFYING THE PROBLEM: (AIM): What were you trying to find out? **(2)**

1.1 IDENTIFYING AND CONTROLLING VARIABLES: What were your variables?

1.1.1 Independent variable
1.1.2 Dependent variable
1.1.3 Control variables (more than one)

1.2 STATING HYPOTHESIS

1.2.1 Investigative question? What will happen to…if (or any other form) **(2)**
1.2.2 State the hypothesis. Make a prediction:- (If …then…) or any other form.

1.3 OPERATIONAL DEFINITIONS: How are you going to collect data/observation?
(E.g. the growth of the plant will be measured by a ruler using centimeters after every 12hrs)

1.4 EXPERIMENTAL DESIGN

1.4.1 CARRYING OUT THE EXPERIMENT (PROCEDURE):- Write a procedure, or a description of how the experiment will be carried out.

1.4.2 Results must be recorded in a suitable way, preferably in a table with at least five (5) different values. Attention must be paid to details of entry; e.g., accuracy, proper units. Where possible, have readings been repeated for accuracy?

1.5 GRAPHING AND INTERPRETING DATA

1.5.1 **GRAPHING**:
Present your results in the line graph using a graph paper. It must have:-

(i) a title **(2)**
(ii) a correctly labeled axes. **(2)**
(iii) a sensible choice of scale **(2)**
(iv) all points clearly indicated on the graph **(4)**
(v) accuracy (best fits points and shape) **(2)**

1.5.2 **INTERPRETING DATA**
Using the information on the graph to interpret and evaluate your findings (results)

1.6 **CONCLUSION**: From 1.5 above, can you draw a conclusion? (Take your controlled variables into consideration. From the results, it can be concluded that …………………… (use the relationship between the independent and dependent variables/ Verify your hypothesis)

---***[Marking memo=16 +Marking rubric=24: Total=40]***

Appendix E: Practical investigation report marking rubric

Name of school: ______________________

Name of Learner: ______________________ Grade: ____________

Assessor: ______________________ Date of assessment: ____________

Practical Investigation: Task number: ______________________

Topic: ______________________

ASSESSMENT RUBRIC FOR PRACTICAL INVESTIGATION

	Level Descriptors					
Integrated Science Process Skills	**0**	**1**	**2**	**3**	**Weight**	**Score**
Identifying & controlling variables	All variables identified are incorrect.	Any one of the variables is correctly identified.	Any two of the variables are correctly identified.	The independent, dependent and two (2) control variables are correctly identified.	1	3
Stating Hypothesis	Not attempted	Hypothesis stated but not related to the investigation	Hypothesis clearly stated and linked to investigation	Hypothesis clearly stated and linked to investigation with the relationship between variables clearly outlined	1	3
Operational definitions	Not attempted	Statement (s) do(es) not provide measurable variable (s)	Statement (s) do(es) provide measurable variable (s) but cannot give solution	Statement (s) do(es) provide measurable variable (s) and can give a solution	1	3
Experimental design	• Does not show a plan to collect, record and evaluate data. • Plan to collect, record and evaluate data will not solve the problem.	Plan deals only with collecting and /or recording and/or evaluating the data and all are not appropriate to solve the problem.	Any two of 'collecting', 'recording' or 'evaluating' is appropriate to solve the problem.	Plan to collect, record and evaluate data is appropriate to solve the problem.	3	9
Graphing & interpreting	Wrong or not meaningful manipulation of data (e.g. incorrect formulae, equations, calculations or graphs)	• Insufficient manipulation of data • Some correct calculations, formulae and equations	• Meaningful and purposeful manipulation of data (e.g. correct calculations, formulae or equations) • Uses a variety of methods to interpret results	• Correct methods of interpretation and appropriate translations(e.g. table to line graph) • Most calculations, formulae and equations are correct • Uses a variety of methods to interpret results	2	6
Total						24

GRAND TOTAL (Memo mark (16) + Rubric mark (24): ____________/ 40

Modified from Limpopo Education Department: Physical sciences Curriculum, Practical investigations grade 11& 12, 2012

Appendix F$_1$: Practical investigation report marking memorandum- task 1

MEMO FOR PRACTICAL INVESTIGATION 1 (THE PENDULUM)

NAME OF A LEARNER:…………………………………………………………………………

NAME OF SCHOOL:…………………………………………………………………………

GRADE……………………………………………… DATE…………………………………

Title of investigation

The length of the pendulum and its period.

1.0 IDENTIFYING THE PROBLEM: (AIM)

To investigate the relationship between the length of the pendulum and the its period **(2)**

1.1 IDENTIFYING AND CONTROLLING VARIABLES

1.1.1 Independent variable: Length of the pendulum (l).

1.1.2 Dependent variable: Period (T).

1.1.3 Controlled variables: Number of swings, Mass of stone (weight), type of string, air resistance, the angle/position where the stone is released to swing, etc.

1.2 STATING HYPOTHESIS

1.2.1 Investigative question: Will the period of the pendulum change when the length of the string is changed? **(2)**

1.2.2 State the hypothesis. When the length of the pendulum is increased/decreased it takes a longer/shorter (remains the same) period to complete an oscillation.

1.3 OPERATIONAL DEFINITIONS: The length of the pendulum will be measured using a ruler. The time (t) taken for a pendulum to make five swings per trial will be measured using a stop watch.

1.4 EXPERIMENTAL DESIGN

1.4.1 CARRYING OUT THE EXPERIMENT (PROCEDURE):

i) Put the retort stand on a flat surface.

ii) Measure the length of the string.

iii) Tie one end of the string to the retort stand and the other to a stone /weight.

iv) Pull the stone/weight to a measured angle when at rest.

v) Release the stone to swing and simultaneously switching on the stop watch.

vi) Count five swings and immediately stop the watch.

vii) Record the time taken for the five swings.

viii) Repeat steps (iv)-(vii) in each trial 3 times to get the average results.

ix) Change the length of the string and repeat steps (ii)-(viii)

vii) Record the results in a table.

1.4.2 TABLE OF RESULTS

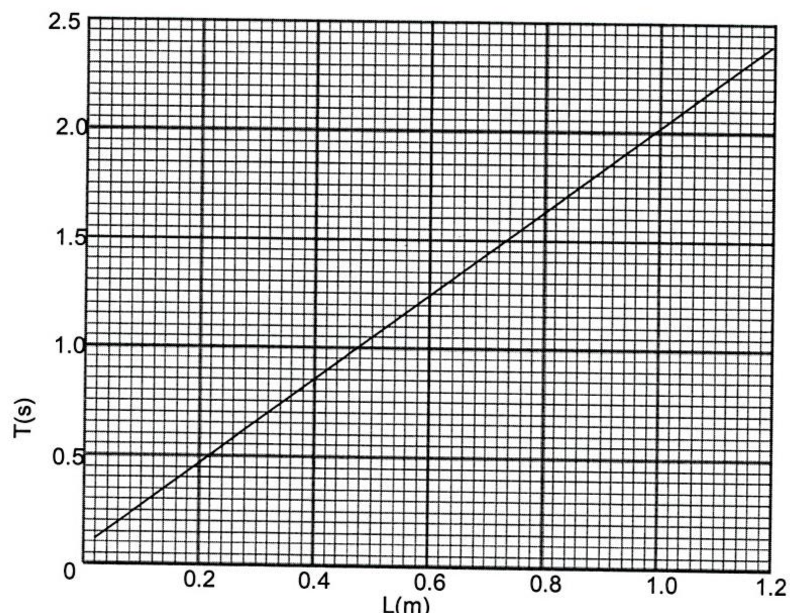
Trial	Length of string (m)	Mass of stone (kg)	Time taken for 5 swings/period of pendulum(s)
1	0,2	0,02	1,01(Average)
2	0,4	0,02	1,24
3	0,6	0,02	1,61
4	0,8	0,02	1,86
5	1.0	0,02	2,00

NB: Each trial must be repeated may be three times to obtain (calculate) the average time time taken (period of the pendulum) for the number of swings.

1.5 GRAPHING AND INTERPRETING DATA

1.5.1 GRAPHING

Graph showing the relationship between length and period of the pendulum.



Marking grid

Criteria	Level description	Mark(s)	
Title	Y versus X-axes graph	✓✓	(2)
Axes labels	Y-axis and X-axis labeled with units	✓✓	(2)
Scaling	Consistency in Y-axis and X-axis scales	✓✓	(2)
Plotting	Five points correct plotted as from table	✓✓ ✓✓	(4)
Line of best fit & shape	Points of best fit drawn	✓✓	(2)

1.5.2 INTERPRETING DATA

A straight line graph, this is because as the concentration of HCℓ increases so the amount of $H_2(g)$ formed/ change in temperature also increases. When the concentration of HCℓ is increased, the amount of hydrogen formed/ change in temperature also increase, hence the volume of $H_2(g)$/ heat released increases.

1.6 CONCLUSION:

Concentration of HCℓ is proportional to the amount of hydrogen gas /heat produced. This is because as the concentration of HCℓ is increased, the amount of hydrogen ions increases in a reaction, then more hydrogen gas is formed/ heat released will increase.

--- ***[16]***

Appendix F_2: Practical investigation report marking memorandum: task 2

MEMO FOR PRACTICAL INVESTIGATION 2 (CHℓ-Zn REACTION)

NAME OF A LEARNER:..

NAME OF SCHOOL:…………………………………………………………………...

GRADE………………………………………………… DATE……………………………..

Title of investigation

To determine whether the amount of hydrogen gas formed/ heat released will depend on the concentration of HCℓ.

1.0 IDENTIFYING THE PROBLEM: (AIM)

To find out whether the amount of $H_{2(g)}$ produced / heat released will depend ✓on an increase on the concentration of HCℓ ✓when HCℓ reacts with excess Zn **(2)**

1.1 IDENTIFYING AND CONTROLLING VARIABLES

1.1.1 Independent variable: Concentration of HCℓ

1.1.2 Dependent variable: Amount of heat released/Change in temperature/Amount of hydrogen gas released.

1.1.3 Controlled variables: Mass of Zn, Volume of HCℓ, Same temperature/environment, etc.

1.2 STATING HYPOTHESIS

1.2.1 Investigative question: Will the amount of hydrogen gas formed/ heat released increase✓ as the concentration increases or not✓? **(2)**

1.2.2 State the hypothesis. As the concentration of HCℓ increases/decreases, the amount of the hydrogen gas formed/ heat released increases/decreases.

1.3 OPERATIONAL DEFINITIONS: The amount of hydrogen gas formed will be collected in the gas syringe and measured after the reaction reaches completion. OR The change in temperature (representing the heat released) will be measured using a thermometer during the start of the reaction and after the reaction reaches completion.

1.4 EXPERIMENTAL DESIGN

1.4.1 CARRYING OUT THE EXPERIMENT (PROCEDURE):

i) Take 5 test tubes/ glass jars and label them 1, 2, 3, 4 and 5 respectively

ii) Place/pour Zn metal of 5g in each test tube and add 5cm³ of HCℓ (aq) of known concentration in each test tube.

iii) Simultaneously close the test tubes with a rubber stopper with a delivery tube connected to syringe.

iv) Shake each test tube to ensure that the reactions run until they are complete.

v) Measure the amount of $H_2(g)$ formed in each syringe and record the observations.

vi) Repeat step 1-5 in each experiment 3 times to ensure that the results are accurate.

vii) Summarise the observations in a table.

1.4.2 TABLE OF RESULTS

Experiment	1	2	3	4	5
Concentration of HCℓ ($mol.dm^{-3}$)	0.1	1.0	2	11	18
Volume of $H_{2(g)}$ formed (cm^3)	0.2	1	2.8	6.3	9.8

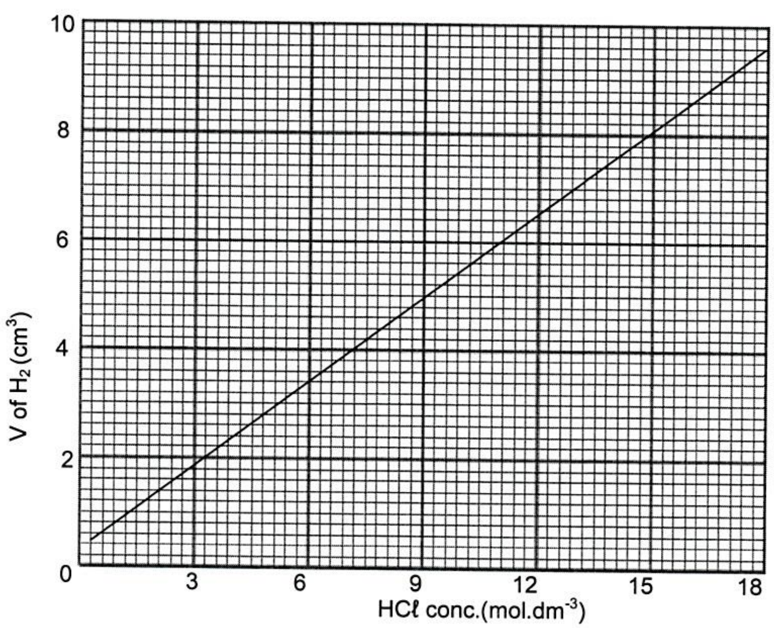
OR

Experiment	1	2	3	4	5
Concentration of HCℓ ($mol.dm^{-3}$)	0.1	1.0	2	11	18
Change in temperature (^oC)	4	6	10	15	21

1.5 GRAPHING AND INTERPRETING DATA

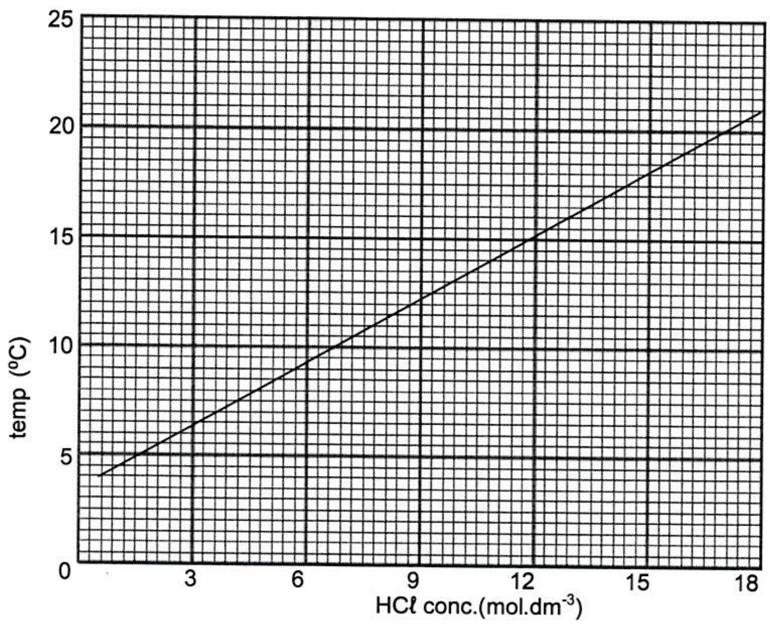
1.5.1 GRAPHING

Graph showing the relationship between HCℓ concentration and H_2 (g) released when it reacts with excess Zn granules



OR

Graph showing the relationship between HCℓ concentration and heat released when it reacts with excess Zn granules



Marking grid

Criteria	**Level description**	**Mark(s)**	
Title	Y versus X-axes graph	✓✓	**(2)**
Axes labels	Y-axis and X-axis labeled with units	✓✓	**(2)**
Scaling	Consistency in Y-axis and X-axis scales	✓✓	**(2)**
Plotting	Five points correct plotted as from table	✓✓ ✓✓	**(4)**
Line of best fit & shape	Points of best fit drawn	✓✓	**(2)**

1.5.2 **INTERPRETING DATA**

A straight line graph, this is because as the concentration of HCℓ increases so the amount of $H_2(g)$ formed/ change in temperature also increases. When the concentration of HCℓ is increased, the amount of hydrogen formed/ change in temperature also increase, hence the volume of $H_2(g)$/ heat released increases.

1.6 CONCLUSION:

Concentration of HCℓ is proportional to the amount of hydrogen gas /heat produced. This is because as the concentration of HCℓ is increased, the amount of hydrogen ions increases in a reaction, then more hydrogen gas is formed/ heat released will increase.

-- ***[16]***

Appendix G: Questionnaire

Research Questionnaire

The following questions seek for your reflection about the research based on comparison of group and individual practical investigations on the development of integrated science process skills that you participated on either as individual or in a group.

The reason is to find out how you understand and view the research process undertook related to the practical investigations. Note that all your responses are important and appreciated.

i) Were you participating in a group or as individual in the practical investigations? (Choose one):..

ii) What did you enjoy during the investigation? ....
Explain your answer.
....
....
....
....
....

iii) Did you gain any science process skills during the practical investigations?....................
If yes, name the skill(s):..
....
....
....

iv) What did you find difficult during the investigation?
....
....
....
....
....

v) How did you make decisions about what to do during the investigation?
....
....
....
....
....

vi) Do you think you learnt something that you can use in other investigations?..........
Please explain:...
....
....
....
....

vii) Did the investigation help you to understand science better?......................
Please explain:..
....
....
....
....
....

viii) Do you think working alone (individually) /in group is better? (Choose).................
Please explain:..
....
....
....
....
....
....

ix) Is there any difference in your understanding of concepts/ terms/skills before and after the investigation. ....
Please explain:..
....
....
....
....

x) What do you think about your performance between the pre-test and the post-test?
....
....
....
....

xi) Is there anything else regarding the investigation that you would like to share with us?
....
....
....
....
....

Thank you for your participation and your contribution is highly valued.

Appendix H: Pilot study learners scores

Scores of pilot study for pre-test, post-test and practical reports

Learners Code				Pre-test scores						Post-test scores						Practical reports scores		
ID Code	School	Gender	Treatment	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	PR1 (40)	PR2(40)	PRAV(40)
1	P	M	I	4	3	1	1	0	9	6	2	2	7	0	17	24	27	25.5
2	P	M	I	4	0	1	3	2	10	4	1	1	4	1	11	23	*	11.5
3	P	F	I	3	1	2	3	2	11	3	0	0	4	1	8	15	*	7.5
4	P	F	I	3	0	2	2	1	8	4	2	2	2	1	11	12	16	14
5	P	M	G	3	2	3	4	0	12	4	2	4	1	0	11	30	23	26.5
6	P	M	G	1	0	0	3	1	5	4	1	2	5	1	13	23	21	22
7	P	F	G	1	1	1	2	0	5	4	3	1	4	2	14	19	32	25.5
8	P	F	G	3	1	1	2	1	8	3	0	2	4	1	10	30	21	25.5
9	P	F	G	4	0	0	1	1	6	2	1	1	2	0	6	16	32	24
10	P	M	G	1	0	1	0	1	3	4	3	3	3	0	13	27	20	23.5
11	P	M	G	5	1	2	4	0	12	4	0	2	2	0	8	36	19	27.5
12	P	F	G	4	2	0	1	3	10	1	0	0	4	1	6	31	19	25
13	P	F	G	2	1	1	2	0	6	4	1	2	2	2	11	36	21	28.5
14	P	M	G	2	1	1	2	0	6	4	1	2	4	0	11	34	23	28.5
15	P	F	G	2	2	0	1	1	6	6	1	1	5	2	15	37	22	29.5
16	P	M	G	1	0	0	1	0	2	5	0	3	8	1	17	36	23	29.5
17	P	F	I	3	1	2	2	0	8	6	2	1	7	0	16	27	23	25
18	P	M	G	5	1	0	1	0	7	4	2	2	6	1	15	25	22	23.5
19	P	M	G	3	1	2	3	0	9	3	1	2	4	1	11	15	17	16
20	P	M	I	2	1	1	2	0	6	1	0	1	3	2	7	28	23	25.5
21	P	M	G	2	0	1	2	0	5	2	0	2	0	0	4	31	20	25.5
22	P	F	G	1	0	1	3	0	5	4	1	2	2	1	10	26	22	24
23	P	F	G	1	0	1	2	0	4	5	1	2	3	2	13	34	28	31
24	P	M	G	2	2	1	2	0	7	3	0	2	4	1	10	30	16	23
25	P	F	I	1	1	1	3	1	7	4	1	1	7	0	13	16	0	8
26	P	M	G	3	1	1	4	0	9	8	3	3	4	1	19	25	23	24
27	P	M	I	1	2	1	2	1	7	4	2	2	3	2	13	18	0	9
28	P	M	G	3	2	1	2	0	8	3	1	2	5	1	12	21	27	24
29	P	F	G	4	0	1	2	1	8	1	0	0	2	1	4	29	22	25.5
30	P	F	G	2	1	2	2	1	8	4	1	3	6	1	15	26	26	26
31	P	M	G	0	2	2	1	0	5	2	2	3	5	2	14	32	18	25
32	P	F	G	1	1	1	1	0	4	1	2	1	2	1	7	22	12	17

33	P	M	I	3	1	1	1	1	7	6	2	2	7	1	18	30	29	29.5
34	P	F	I	3	0	1	2	0	6	1	1	2	3	0	7	40	11	25.5
35	P	F	G	1	0	2	2	0	5	3	3	3	7	1	17	31	19	25
36	P	M	G	3	1	2	4	1	11	4	3	4	5	0	16	18	17	17.5
37	P	M	G	2	1	2	2	1	8	4	1	2	3	2	12	13	21	17
38	P	M	G	4	3	0	2	1	10	5	2	1	4	0	12	19	25	22
39	P	F	I	2	0	3	5	1	11	3	1	5	5	2	16	36	28	32
40	P	F	I	3	0	4	4	2	13	5	2	6	8	2	23	33	23	28
41	P	M	I	5	1	3	4	2	15	7	2	4	6	2	21	34	19	26.5

Key: Participant code:

01PMI represents (01 = Learner number 1, P = Pilot school, M = Male and I = Individual treatment (practical investigation)
07PFG represents (07 = Learner number 7, P = Pilot school, F= Female and G = Group treatment (practical investigation)
Gender: M = Male F = Female
ISPS1 (8) = Integrated Science Process Skill 1 (to identify and control variables): score out of 8 marks
ISPS2 (4) = Integrated Science Process Skill 2 (to state hypothesis): score out of 4 marks
ISPS3 (6) = Integrated Science Process Skill 3 (to operationally define variables): score out of 6 marks
ISPS4 (9) = Integrated Science Process Skill 4 (to design experiments): score out of 9 marks
ISPS5 (3) = Integrated Science Process Skill 5 (to draw and interpret data)" score out of 3 marks
PR1(40) = Practical report 1: score out of 40 marks
PR2(40) = Practical report 2: score out of 40 marks
PRAV(40) = Practical report average (PR1 + PR2 divided by 2): score out of 40 marks
* = Task not submitted

Appendix I: Main study group treatment learners' scores

Scores for Group practical investigation learners

Learner Code				Pre-test scores						Post-test scores						Practical reports score
ID Code	School	Gender	Treatment	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	PR1 (40)
3	S	G	M	2	2	1	1	1	7	4	3	0	1	1	9	21
4	S	G	F	4	1	4	6	1	16	3	1	3	2	1	10	20
6	S	G	M	3	2	3	6	2	16	2	1	0	5	0	8	19
7	S	G	F	4	1	2	3	1	11	3	0	2	1	0	6	24.5
8	S	G	M	3	0	1	6	2	12	1	3	2	9	0	15	14.5
9	S	G	F	4	1	0	2	1	8	3	1	2	3	0	9	26
10	S	G	F	5	2	3	5	2	17	5	2	2	3	2	14	24.5
12	S	G	M	3	3	2	4	0	12	4	3	1	6	0	14	18.5
14	S	G	M	5	2	3	4	1	15	3	4	2	4	0	13	16.5
15	S	G	M	2	2	2	2	2	10	2	3	1	3	3	12	24
16	S	G	M	4	2	4	2	1	13	3	3	3	3	1	13	25.5
17	S	G	F	2	2	3	3	1	11	6	0	3	3	1	13	30.5
18	S	G	M	6	3	1	5	1	16	3	1	1	4	2	11	28
19	S	G	M	2	2	1	1	0	6	2	1	3	1	2	9	29
20	S	G	M	4	1	1	6	2	14	6	2	2	6	2	18	26
21	S	G	F	4	1	3	5	1	14	4	3	2	6	0	15	30.5
23	S	G	M	4	2	3	2	2	13	3	1	0	1	1	6	22.5
24	S	G	F	4	2	3	2	1	12	5	2	3	4	2	16	9.5
25	S	G	F	2	2	2	2	0	8	1	2	2	2	0	7	19.5
26	S	G	M	7	2	1	6	3	19	7	1	3	3	3	17	20
27	S	G	M	3	1	3	5	2	14	2	0	1	5	1	9	21
28	S	G	M	4	1	1	3	0	9	1	1	2	3	1	8	10
29	S	G	M	4	2	2	2	1	11	6	1	2	6	3	18	0
30	S	G	F	3	1	0	3	1	8	3	2	3	4	0	12	25
31	S	G	F	3	2	1	3	1	10	4	1	0	3	0	8	22
32	S	G	F	2	1	4	3	1	11	4	2	2	3	1	12	16.5
33	S	G	F	5	1	3	5	2	16	2	1	3	5	1	12	16.5
35	S	G	F	3	2	0	3	0	8	4	2	2	2	0	10	23.5
36	S	G	F	5	2	2	4	2	15	6	2	2	2	2	14	21.5
37	S	G	F	4	1	2	2	0	9	3	0	5	3	0	11	9.5
38	S	G	F	3	0	3	5	1	12	3	0	2	5	2	12	23

39	S	G	F	3	0	4	5	1	13	3	0	4	5	1	13	25
40	S	G	F	2	1	0	4	2	9	4	0	1	4	1	10	23
41	S	G	M	5	0	4	5	1	15	2	0	1	4	0	7	11
42	S	G	M	5	3	2	5	1	16	5	2	3	6	1	17	28.5
43	S	G	F	2	1	0	4	1	8	2	1	3	3	0	9	14.5
45	S	G	M	6	2	0	6	1	15	4	2	1	5	2	14	17.5
46	S	G	F	4	2	1	3	1	11	4	2	2	3	0	11	26.5
48	S	G	F	3	3	1	5	1	13	5	3	1	5	0	14	27
49	S	G	F	3	2	5	7	0	17	6	0	2	4	3	15	25.5
50	S	G	M	3	0	1	1	1	6	4	2	2	6	2	16	14
52	S	G	M	4	2	2	6	1	15	5	3	3	7	2	20	25
53	S	G	M	4	3	2	5	1	15	6	2	2	6	1	17	31
54	S	G	F	2	1	2	2	0	7	1	2	1	3	0	7	30.5
55	S	G	F	3	0	0	3	2	8	2	1	4	4	2	13	28.5
59	S	G	F	6	2	1	6	2	17	6	3	3	7	2	21	27.5
60	S	G	F	2	0	2	2	0	6	4	0	2	1	0	7	22
61	S	G	F	6	3	2	6	1	18	6	2	2	6	2	18	21
62	S	G	F	2	1	3	4	1	11	5	3	2	5	0	15	11
63	S	G	F	4	0	0	3	0	7	1	1	1	1	0	4	23
66	S	G	M	4	0	2	4	0	10	6	2	2	4	1	15	26.5
67	S	G	F	5	1	2	5	2	15	7	2	5	5	1	20	30.5
68	S	G	M	6	2	1	4	3	16	4	3	2	4	1	14	15
69	S	G	F	3	2	3	2	0	10	7	2	3	5	1	18	16
70	S	G	M	5	2	2	4	0	13	5	1	4	4	1	15	9
71	S	G	F	4	2	0	2	0	8	4	2	3	2	1	12	22
73	S	G	F	1	2	1	3	1	8	3	1	3	3	2	12	26.5
74	S	G	F	5	1	2	3	1	12	6	0	1	6	2	15	28.5
75	S	G	F	1	3	0	5	0	9	1	2	0	4	0	7	25.5
76	S	G	F	4	3	1	4	2	14	4	1	2	5	1	13	34.5
77	S	G	F	2	1	4	1	1	9	3	1	3	1	0	8	29
78	S	G	F	3	1	4	2	1	11	2	1	5	2	0	10	21
79	S	G	M	2	2	4	4	1	13	3	2	2	3	0	10	20.5
80	S	G	F	2	1	1	5	1	10	3	1	3	4	2	13	31.5
84	S	G	F	4	0	0	4	0	8	4	2	0	5	1	12	27.5
85	S	G	M	1	1	3	2	2	9	3	2	1	4	2	12	20
86	S	G	F	1	1	1	2	1	6	2	3	4	3	0	12	28.5
87	S	G	M	1	2	2	4	1	10	2	1	2	6	0	11	25
88	S	G	M	4	3	4	5	1	17	6	2	2	4	1	15	26.5
89	S	G	F	1	2	1	3	2	9	3	2	1	5	2	13	27
91	S	G	M	1	3	1	3	1	9	3	2	2	3	0	10	19
93	S	G	M	3	1	2	3	0	9	2	1	1	4	0	8	22

94	S	G	F	7	1	2	4	1	15	5	2	2	6	2	17	26.5
95	S	G	M	2	1	3	6	3	15	1	1	1	3	1	7	15
96	S	G	M	4	2	1	4	2	13	5	2	2	5	2	16	19.5
97	S	G	M	3	3	0	3	2	11	3	2	1	3	0	9	6.5
98	S	G	F	7	3	3	5	2	20	7	3	3	6	2	21	30.5
99	S	G	F	3	3	3	6	2	17	3	2	4	5	3	17	33.5
100	S	G	F	4	1	1	4	1	11	4	1	2	5	0	12	32
103	S	G	F	1	1	1	3	0	6	3	3	0	2	0	8	31.5
104	S	G	F	2	1	1	2	1	7	2	0	4	1	1	8	23.5
105	S	G	F	1	1	2	2	1	7	3	0	4	3	1	11	19
107	S	G	F	1	1	2	3	2	9	5	1	2	4	2	14	29.5
110	S	G	M	4	0	3	7	0	14	1	1	3	4	1	10	14.5
112	S	G	F	4	0	1	5	1	11	3	0	2	3	2	10	30.5
114	S	G	F	7	0	3	5	2	17	4	0	4	3	2	13	26.5
115	H	G	F	3	3	3	6	2	17	3	3	2	6	1	15	9.5
118	H	G	F	5	1	3	6	1	16	4	1	2	4	1	12	35.5
119	H	G	M	4	1	2	7	2	16	4	2	1	4	1	12	16.5
120	H	G	M	3	2	3	3	3	14	3	1	2	1	1	8	25
121	H	G	M	5	2	2	3	0	12	2	1	0	2	2	7	25
122	H	G	F	3	1	1	3	1	9	3	3	1	1	0	8	11.5
123	H	G	F	5	1	0	4	0	10	5	0	2	4	2	13	17.5
125	H	G	M	3	1	3	4	1	12	3	1	0	3	2	9	20.5
126	H	G	F	2	2	1	2	2	9	1	1	2	0	1	5	20.5
127	H	G	M	6	2	1	5	1	15	4	2	4	5	1	16	18.5
129	H	G	F	4	2	2	6	0	14	4	1	4	7	1	17	18
130	H	G	F	2	2	1	3	1	9	4	2	2	3	1	12	22.5
131	H	G	F	3	2	3	5	1	14	4	1	1	5	0	11	18
132	H	G	M	3	2	3	4	0	12	5	2	2	7	1	17	19.5
133	H	G	F	1	1	3	3	0	8	1	0	1	3	1	6	21.5
134	H	G	M	4	1	2	4	2	13	2	0	2	4	1	9	1
135	H	G	M	7	3	3	4	3	20	4	3	3	5	2	17	21
137	H	G	F	1	1	2	3	1	8	2	2	1	2	1	8	14.5
139	H	G	F	3	1	0	5	2	11	4	3	0	3	1	11	23.5
140	H	G	F	3	1	4	3	2	13	3	2	1	7	0	13	19.5
141	H	G	M	1	1	4	2	0	8	1	0	4	6	0	11	25.5
142	H	G	F	4	2	2	6	1	15	3	0	3	4	1	11	10.5
143	H	G	F	4	0	3	4	2	13	6	1	3	6	2	18	16.5
144	H	G	F	6	2	5	6	3	22	7	2	3	5	2	19	23.5
145	H	G	F	2	0	2	3	0	7	3	0	2	2	2	9	21.5
146	H	G	M	4	0	1	2	1	8	4	2	2	4	0	12	11.5
147	H	G	F	2	1	2	4	0	9	1	3	3	3	0	10	16.5

148	H	G	M	3	2	5	4	2	16	6	1	5	8	2	22	30.5
150	H	G	F	4	2	3	2	0	11	2	0	1	4	0	7	15.5
152	H	G	M	3	3	4	4	0	14	2	2	1	1	1	7	17
153	H	G	M	5	2	2	6	1	16	7	1	2	5	2	17	28.5
155	H	G	F	4	3	1	5	0	13	7	3	2	5	0	17	13.5
157	H	G	F	6	0	2	6	1	15	5	1	2	5	1	14	23
159	H	G	M	4	2	1	4	2	13	2	2	2	6	2	14	22
160	H	G	F	4	0	2	1	2	9	1	0	2	2	1	6	14.5
161	H	G	M	2	1	1	2	0	6	2	2	1	2	2	9	6.5
162	H	G	M	5	1	2	5	2	15	3	2	2	2	1	10	19.5
163	H	G	M	4	1	1	3	1	10	3	2	1	2	2	10	1
164	H	G	M	5	1	5	7	2	20	3	2	2	3	0	10	15.5
167	H	G	F	3	2	1	4	1	11	1	1	0	1	1	4	17
168	H	G	M	5	2	4	5	1	17	4	1	5	6	1	17	13.5
169	H	G	F	3	0	3	2	0	8	1	0	1	3	1	6	14
170	H	G	M	6	1	2	2	1	12	3	1	1	3	0	8	18.5
171	H	G	F	4	2	2	2	2	12	2	1	2	1	2	8	18
172	H	G	F	4	1	2	5	1	13	4	3	5	6	1	19	34.5
173	H	G	F	3	3	2	3	1	12	3	1	2	5	1	12	21.5
174	H	G	M	2	2	0	4	1	9	2	1	2	4	1	10	18
175	H	G	F	3	1	3	6	1	14	5	1	4	4	0	14	24
176	H	G	F	2	1	1	4	0	8	3	1	0	4	0	8	18.5
177	H	G	F	6	1	4	6	3	20	4	2	1	4	2	13	26
180	H	G	M	7	2	4	7	3	23	6	2	2	7	2	19	19.5
183	H	G	F	1	0	1	2	0	4	2	2	1	3	0	8	18.5
184	H	G	F	4	2	1	2	1	10	4	2	2	2	0	10	21
185	H	G	F	4	1	5	5	0	15	4	2	2	4	1	13	16.5
187	H	G	M	4	2	2	5	2	15	4	2	3	7	2	18	15
188	H	G	M	3	1	1	3	2	10	1	1	2	3	2	9	29
189	H	G	M	3	2	1	1	0	7	3	2	2	4	0	11	13
191	H	G	F	3	1	1	4	0	9	4	2	2	2	0	10	17.5
192	H	G	F	5	1	2	2	1	11	2	2	3	2	2	11	16.5
194	Y	G	F	2	1	3	1	0	7	1	1	2	3	0	7	13.5
195	Y	G	F	4	3	4	6	1	18	5	2	3	7	2	19	22
196	Y	G	M	5	2	3	7	1	18	4	2	4	8	1	19	14
197	Y	G	M	4	2	3	5	2	16	2	2	1	5	1	11	21.5
198	Y	G	F	3	2	2	1	0	8	5	1	3	3	1	13	8
200	Y	G	F	2	2	0	1	0	5	2	3	0	0	0	5	5
201	Y	G	F	4	0	3	4	2	13	4	0	1	2	2	9	13
202	Y	G	F	1	3	3	2	2	11	2	3	3	3	0	11	21
204	Y	G	M	4	2	5	7	2	20	5	2	5	7	2	21	23.5

205	Y	G	F	3	2	4	4	2	15	4	1	3	6	2	16	20
206	Y	G	M	4	2	4	5	3	18	6	2	4	6	2	20	11
207	Y	G	F	5	2	2	2	1	12	4	2	4	3	1	14	23
208	Y	G	M	3	1	2	3	0	9	3	2	0	5	1	11	24
210	Y	G	F	3	2	5	3	0	13	2	2	1	4	0	9	22.5
211	Y	G	F	5	1	0	4	2	12	5	1	3	6	2	17	12
212	Y	G	F	4	3	3	6	1	17	5	2	3	5	0	15	12.5
213	Y	G	F	3	1	1	3	0	8	2	1	3	2	0	8	0
215	Y	G	M	1	0	2	1	0	4	1	0	2	1	1	5	10.5
217	Y	G	F	3	3	2	5	1	14	3	1	2	2	0	8	4.5
218	Y	G	F	4	0	4	3	1	12	3	1	3	4	1	12	18
221	Y	G	M	3	2	4	0	0	9	4	3	2	1	2	12	18.5
224	Y	G	F	3	1	3	3	0	10	3	1	1	1	0	6	23
225	Y	G	F	3	1	2	6	2	14	4	2	3	7	2	18	19
226	Y	G	F	3	1	1	0	2	7	4	4	2	2	1	13	16.5
227	Y	G	F	1	0	1	4	0	6	0	2	2	5	0	9	13.5
228	Y	G	F	6	3	3	5	2	19	6	2	5	7	2	22	29.5
229	Y	G	F	6	3	3	7	3	22	6	3	6	7	3	25	1.5
231	Y	G	M	3	2	3	2	0	10	4	0	2	1	3	10	12
233	Y	G	M	2	1	4	3	1	11	6	1	2	5	0	14	14.5
234	Y	G	M	4	1	4	4	2	15	4	2	2	4	2	14	16
235	Y	G	F	4	2	2	6	2	16	5	2	3	7	3	20	25
237	Y	G	M	3	1	2	5	2	13	3	1	2	4	1	11	12.5
238	Y	G	M	3	2	1	6	1	13	6	3	2	5	2	18	18.5
240	Y	G	M	3	2	3	6	2	16	4	1	3	3	2	13	1
241	Y	G	F	6	2	2	4	1	15	5	1	2	5	2	15	20
243	Y	G	F	2	1	1	3	1	8	4	3	1	5	2	15	15
245	Y	G	F	5	2	0	1	2	10	3	2	1	2	0	8	25.5
246	Y	G	F	2	0	1	4	0	7	3	2	1	5	3	14	11
247	Y	G	F	5	0	4	5	1	15	3	0	2	6	0	11	0
248	Y	G	F	3	1	1	3	0	8	4	1	1	4	1	11	21.5
249	Y	G	F	3	0	1	3	0	7	3	0	3	3	0	9	6.5
251	Y	G	M	2	3	3	3	2	13	5	1	2	6	1	15	23.5
252	Y	G	F	4	1	3	4	1	13	2	1	2	6	1	12	15
255	N	G	M	2	0	0	2	0	4	2	1	1	6	0	10	23.5
256	N	G	M	5	2	1	2	1	11	1	4	2	4	0	11	25.5
257	N	G	F	4	2	4	6	3	19	6	0	4	5	3	18	22.5
258	N	G	F	2	2	5	5	0	14	3	2	3	3	0	11	22
259	N	G	M	3	1	3	4	2	13	5	0	2	4	2	13	9.5
261	N	G	F	5	3	5	7	2	22	4	2	5	6	1	18	34
263	N	G	M	4	2	2	5	1	14	4	3	2	6	0	15	4.5

264	N	G	F	3	0	1	2	1	7	2	1	2	4	1	10	17.5
265	N	G	F	4	1	4	4	2	15	3	2	2	7	1	15	21
266	N	G	M	0	2	3	7	1	13	4	2	5	6	1	18	23.5
267	N	G	F	5	1	3	5	1	15	2	2	2	6	2	14	19.5
269	N	G	M	6	3	3	5	1	18	6	3	3	3	1	16	25
271	N	G	M	2	2	0	4	1	9	3	2	1	5	2	13	28
272	N	G	M	4	2	3	5	3	17	5	1	1	2	2	11	27
273	N	G	M	5	0	3	5	1	14	3	3	1	2	1	10	17.5
275	N	G	M	1	1	1	2	1	6	4	2	2	2	1	11	17.5
276	N	G	M	2	2	1	6	0	11	3	0	2	5	1	11	25
278	N	G	M	1	1	1	3	2	8	1	1	1	4	2	9	11.5
279	N	G	F	4	2	3	3	0	12	3	2	2	3	2	12	4
280	N	G	F	3	1	1	5	0	10	4	1	1	1	0	7	26
281	N	G	F	1	1	2	3	0	7	3	0	3	3	0	9	18.5
282	N	G	F	1	1	2	4	0	8	1	2	1	6	0	10	16.5
283	N	G	F	3	2	3	7	1	16	6	2	3	4	2	17	15
285	N	G	F	4	1	4	4	2	15	1	1	2	3	1	8	19
286	N	G	M	5	1	3	4	0	13	3	3	2	2	2	12	28
287	N	G	F	5	2	4	6	3	20	4	1	5	1	2	13	11.5
288	N	G	M	4	0	1	3	3	11	5	2	2	5	0	14	23
289	N	G	F	4	2	4	5	0	15	5	2	1	2	0	10	23.5
290	N	G	F	5	2	1	2	2	12	5	1	2	2	2	12	24
291	N	G	M	6	1	2	6	2	17	3	2	1	3	1	10	17.5
292	N	G	M	4	1	3	5	1	14	4	2	5	6	2	19	28
293	N	G	F	3	0	1	3	1	8	3	2	2	4	0	11	16.5
294	N	G	M	6	3	2	4	2	17	2	2	2	6	1	13	16
295	N	G	F	3	0	2	5	0	10	3	2	5	2	0	12	25
296	N	G	F	4	0	3	5	1	13	3	1	3	6	1	14	26.5
297	N	G	F	4	1	0	7	1	13	4	2	3	7	2	18	27.5
298	N	G	F	2	1	3	3	0	9	4	2	2	3	0	11	17.5
299	N	G	M	3	2	4	4	3	16	3	1	2	6	2	14	23.5
300	N	G	F	4	1	2	7	0	14	4	0	1	3	1	9	19
301	N	G	M	2	0	1	4	0	7	3	1	3	4	1	12	31.5
302	N	G	M	3	3	2	5	2	15	2	3	4	5	1	15	25.5
305	N	G	F	3	2	1	6	0	12	5	3	2	6	2	18	13.5
308	N	G	M	3	3	1	6	1	14	4	2	3	6	1	16	28.5
309	N	G	M	3	2	3	3	0	11	1	1	3	7	0	12	17
310	N	G	F	5	3	3	5	2	18	3	3	2	7	2	17	31
312	N	G	M	3	2	2	4	2	13	2	2	2	3	2	11	25
313	N	G	F	4	1	3	7	1	16	5	3	3	4	1	16	29.5
315	N	G	M	3	2	1	4	1	11	4	3	3	2	0	12	21.5

316	N	G	F	5	3	3	7	2	20	5	1	5	4	2	17	25
317	N	G	M	2	3	5	7	2	19	6	3	4	5	2	20	32.5
318	N	G	M	6	3	5	5	2	21	6	2	3	7	2	20	29.5
319	N	G	F	4	3	1	7	3	18	5	3	4	6	2	20	30

TOTAL NUMBER OF GROUP LEARNERS: 240

Key: Participant code:

3SGM represents (3 = Learner number 3, S = 'S' school, G = Group treatment (practical investigation) M = Male F= Female

ISPS1 (8) = Integrated Science Process Skill 1 (to identify and control variables): score out of 8 marks
ISPS2 (4) = Integrated Science Process Skill 2 (to state hypothesis): score out of 4 marks
ISPS3 (6) = Integrated Science Process Skill 3 (to operationally define variables): score out of 6 marks
ISPS4 (9) = Integrated Science Process Skill 4 (to design experiments): score out of 9 marks
ISPS5 (3) = Integrated Science Process Skill 5 (to draw and interpret data)" score out of 3 marks
PR1(40) = Practical report 1: score out of 40 marks
PR2(40) = Practical report 2: score out of 40 marks
PRAV(40) = Practical report average (PR1 + PR2 divided by 2): score out of 40 marks
* = Task not submitted

Appendix J: Main study individual treatment learners' scores

Scores for Individual practical investigation learners

Learner Code				Pre-test scores						Post-test scores						Practical reports score
ID Code	School	Gender	Treatment	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	ISPS1(8)	ISPS2(4)	ISPS3(6)	ISPS4(9)	ISPS5(3)	ISPSTT(30)	PR1 (40)
1	S	I	F	5	1	3	4	1	14	5	1	4	4	0	14	28.5
2	S	I	F	1	2	3	2	0	8	3	0	2	1	1	7	26.5
5	S	I	M	4	0	4	2	0	10	2	1	1	4	0	8	23
11	S	I	F	7	2	2	6	3	20	8	2	4	8	2	24	14.5
13	S	I	M	2	1	2	5	1	11	6	3	1	6	1	17	24
22	S	I	M	2	3	3	2	2	12	3	1	0	1	1	6	18.5
34	S	I	M	5	1	4	4	1	15	4	2	4	4	0	14	14.5
44	S	I	F	2	2	2	3	1	10	2	0	2	0	1	5	24.5
47	S	I	M	3	1	1	3	2	10	1	1	1	3	2	8	19
51	S	I	F	3	1	2	3	0	9	3	1	1	2	1	8	23.5
56	S	I	F	3	2	4	5	1	15	2	1	5	4	1	13	22.5
57	S	I	M	6	3	3	6	3	21	7	3	2	7	3	22	6
58	S	I	F	2	1	3	2	2	10	2	0	3	3	0	8	25.5
64	S	I	M	1	1	1	0	1	4	2	1	3	1	0	7	8
65	S	I	F	3	2	1	3	0	9	2	3	1	3	0	9	24
72	S	I	M	3	1	0	2	1	7	4	0	1	2	1	8	18
81	S	I	M	2	1	1	4	2	10	3	2	0	2	0	7	19
82	S	I	M	5	2	2	8	1	18	6	3	2	5	1	17	28.5

83	S	I	M	3	1	2	1	0	7	1	2	2	1	0	6	19.5
90	S	I	F	1	0	3	2	1	7	3	1	1	2	0	7	16.5
92	S	I	F	1	2	3	1	1	8	1	1	0	1	1	4	23.5
101	S	I	F	7	3	4	4	2	20	2	1	2	5	2	12	25
102	S	I	F	2	2	1	3	1	9	4	0	2	3	1	10	27
106	S	I	F	3	3	3	4	2	15	5	1	3	7	1	17	29
108	S	I	F	5	2	2	4	2	15	3	1	4	4	2	14	27
109	S	I	F	2	3	4	3	2	14	4	2	1	2	1	10	29
111	S	I	F	3	0	0	2	1	6	6	0	4	3	1	14	21.5
113	S	I	F	5	3	3	5	2	18	2	1	3	5	1	12	21.5
116	H	I	M	6	2	1	6	1	16	4	0	3	2	1	10	26.5
117	H	I	F	3	2	1	2	0	8	3	1	1	2	0	7	16
124	H	I	M	5	2	3	3	2	15	6	2	3	5	2	18	23
128	H	I	M	3	2	2	3	1	11	1	0	1	3	0	5	17
136	H	I	M	5	1	4	7	2	19	4	1	4	5	2	16	30.5
138	H	I	M	4	0	3	3	0	10	1	1	1	3	0	6	14.5
149	H	I	F	2	1	3	1	0	7	2	1	1	0	0	4	16.5

TOTAL NUMBER OF GROUP LEARNERS: 79

Key: Participant code:

22SIM represents (22 = Learner number 22, S = 'S' school, I = Individual treatment (practical investigation) M = Male F= Female

ISPS1 (8) = Integrated Science Process Skill 1 (to identify and control variables): score out of 8 marks
ISPS2 (4) = Integrated Science Process Skill 2 (to state hypothesis): score out of 4 marks
ISPS3 (6) = Integrated Science Process Skill 3 (to operationally define variables): score out of 6 marks
ISPS4 (9) = Integrated Science Process Skill 4 (to design experiments): score out of 9 marks
ISPS5 (3) = Integrated Science Process Skill 5 (to draw and interpret data)" score out of 3 marks
PR1(40) = Practical report 1: score out of 40 marks
PR2(40) = Practical report 2: score out of 40 marks
PRAV(40) = Practical report average (PR1 + PR2 divided by 2): score out of 40 marks
* = Task not submitted

Appendix K: Permission from the University of Pretoria Ethics Committee to conduct research

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Faculty of Education
Ethics Committee
16th January, 2013.

Dear Mr Baloyi,

REFERENCE: SM 12/11/03

Your application was carefully considered and the final decision of the Ethics Committee is:

Your application is approved on the following conditions:

1) Please include the letter of consent to the learners, and be sure to write it in a more understandable and reader friendly language.
2) Kindly also adjust letters to parents to allow second language speakers to understand what the study is about and what their children will be expected to do.

This letter serves as notification that you may continue with your research. You do not have to re-submit an application. The above-mentioned issues can be addressed in consultation with your supervisor who will take final responsibility.

Please note that this is **not a clearance certificate**. Upon completion of your research you need to complete the Integrated Declarations form (D08) that you adhered to all ethics guidelines and conditions stipulated. Subsequently, an Ethics Clearance Certificate will be issued for you to include in your thesis/dissertation before submission.

Please Note:

- ***Any*** *amendments to this approved protocol needs to be submitted to the Ethics Committee for review prior to data collection. Non-compliance implies that approval will be null and void.*

Please quote the reference number **SM 12/11/03** in any communication with the Ethics Committee.

Best wishes,

Dr. Suzanne Bester
Acting Chair: Ethics Committee
Faculty of Education

Appendix L: Permission from the Limpopo Education Department to conduct research

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF EDUCATION

Enquiries: Dr. Makola MC, Tel No: 015 290 9448. E-mail: MakolaMC@edu.limpopo.gov.za.

PRIVATE BAG X9489 POLOKWANE 0700
H.O.D.'S OFFICE
2013 -02- 05
DEPARTMENT OF EDUCATION
LIMPOPO PROVINCE

P .O .Box 266
Masia
0944

Dear Baloyi H.E

RE: Request for permission to Conduct Research

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct a research has been approved- **TITLE: THE EFFECTIVENESS OF GROUP PRACTICAL INVESTIGATIONS ON LEARNERS' ACQUISITION OF INTEGRATED SCIENCE PROCESS SKILLS.**
3. The following conditions should be considered

   3.1 The research should not have any financial implications for Limpopo Department of Education.
   3.2 Arrangements should be made with both the Circuit Offices and the schools concerned.
   3.3 The conduct of research should not anyhow disrupt the academic programs at the schools.
   3.4 The research should not be conducted during the time of Examinations especially the forth term.
   3.5 During the study, the research ethics should be practiced, in particular the principle of voluntary participation (the people involved should be respected).
   3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

Page 1 of 2

Cnr. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE, 0700
Tel: (015) 290 7600. Fax: (015) 297 6920/4220/4494

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4. Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.
5. The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes.

Thamaga MJ

Head of Department

2013/02/05

Date

Page 2 of 2

Appendix M: Permission from Malamulele East circuit office to conduct pilot study

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

Private Bag X9259
SASELAMANI
0928
Tel.: (015) 853 1089

DEPARTMENT OF EDUCATION
MALAMULELE EAST CIRCUIT

REF.:
ENQ.: DR. R.W. CHABALALA

04 MARCH 2013

MR BALOYI H.E
P.O. BOX 266
MASIA

PERMISSION TO CONDUCT RESEARCH PILOT STUDY

1. As discussed telephonically, permission is hereby granted for you to conduct your research pilot study at Dlamani High School.

CIRCUIT MANAGER
MALAMULELE EAST CIRCUIT

DEPARTMENT OF EDUCATION
MALAMULELE EAST CIRCUIT
2013 -03- 04
PRIVATE BAG X 1259
SASELAMANI 0982
LIMPOPO PROVINCE

Appendix N: Permission from Xihoko circuit office to conduct research

LIMPOPO
PROVINCIAL GOVERNMENMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

Private Bag X1413
LETABA
0870
Tel No. 015 303 2154
Fax No. 086 218 9087
Cell No. 071 679 3189

ENQ: Ngomana Magwaza
REF: 81105312

Mr. Baloyi HE
P.O. box 266
Masia
0944

March 26, 2013

Re: Request for permission to conduct academic research: Yourself

1. The above matter has reference
2. In reference to your letter dated March 13, 2013 permission is hereby granted.
3. Consider and adhere to the conditions as stipulated on the letter of permission granted and signed by the HOD, education.
4. I wish you good luck on your endeavour to persue for knowledge.

CIRCUIT MANAGER

DEPARTMENT OF EDUCATION
XIHOKO CIRCUIT MOPANI DISTRICT
2013 -03- 26
DATE
LIMPOPO PROVINCE

Appendix O: Permission from Nkowankowa circuit office to conduct research

Enquiries:

Circuit Letter Head & Address
28 March 2013

Mr. H.E. Baloyi
P.O. Box 266
Masia
0944

Dear Mr. H.E. Baloyi

Re: PERMISSION TO CONDUCT RESEARCH STUDY- HUDSON NTSAN'WISI HIGH SCHOOL

1. This letter bears reference.
2. The Nkowankowa Circuit Office wishes to inform you that your request to conduct the research study towards your masters' degree programme at Hudson Ntsan'wisi High School has been granted.
3. The school has been contacted in this regard, but you are however requested to contact the school management about the research study arrangement and plan in writing.
4. Important: You are reminded to stick to the departmental conditions as stipulated in the HOD's approval letter during your research study engagement.

The Circuit Office wishes you best success in your research study endeavour.

Regards

Circuit Manager

LIMPOPO PROVINCE
DEPARTMENT OF EDUCATION
NKOWANKOWA CIRCUIT
2013 -03- 28
Date
CIRCUIT MANAGER
PRIVATE BAG X 1413 LETABA 0870
TEL: 015 303 1725

Appendix P: Permission from the Klein Letaba circuit office to conduct research

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF EDUCATION
MOPANI DISTRICT

KLEIN LETABA CIRCUIT

Enq: Nyandane, C.F.N
Tel. 015-812 1793

Mr. Baloyi, H.E
P.O. Box 266
MASIA
0944

REQUEST TO CONDUCT AN ACADEMIC RESEARCH STUDY AT HANYANI THOMO: YOURSELF

1. We acknowledge receipt of your letter dated 13 March 2013 regarding the above matter.
2. The circuit approves your request and has contacted the school to allow you to conduct your research on the understanding that you will adhere to the HOD's conditions.
3. The circuit is looking forward to your contribution and wishes you well in your endeavour.

Hope you find this in order.

MACHUMELE, M.M :Circuit Manager

DEPARTMENT OF EDUCATION
THE CIRCUIT MANAGER
KLEIN LETABA CIRCUIT
2013 -04- 10
PRIVATE BAG X9654
GIYANI 0826
LIMPOPO PROVINCE

KLEIN LETABA CIRCUIT
DEPARTMENT OF EDUCATION,
MOPANI DISTRICT, Private Bag X 578 GIYANI, 0826
Tel 015 812 1274 / 015 812 1793 Fax No. 015 812 1141

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Appendix Q: Letter of informed consent to parents

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 002
Repblic of South Africa
Tel: +27 12 420-5734
Fax: +27 12 420-5621

Date: 2nd March 2013

Dear Parent/Guardian (Grade 11 Physical Sciences learner)

Re: Research Study- Grade 11 Physical Sciences learners

My name is Baloyi H.E. (Mr.) and I am doing my Masters studies at the University of Pretoria. I am conducting research about "The effectiveness of group practical investigations on learners' acquisition of integrated science process skills (ISPS)" on grade 11 Physical sciences learners.

The purpose of the research is to find out which teaching strategy is more effective when learners are conducting practical investigations; when working in group or as individuals to acquire the ISPS in the schooling environment.

By participating in the research learners will benefit by:
- gaining scientific knowledge of the different science process skills needed in Physical Sciences.
- acquiring science process skills required in science practical investigations and experiments; which enhance learners problem solving skills and achievement.
- performing recommended practical investigations/experiments in grade 12 (for 2014), which will prepare learners to be ahead in practical work activities knowledge.
- doing hands-on practical activities at their own pace, and
- being assessed on different integrated science process skills.
- gaining more knowledge on research projects (one of their formal practical work activity in grade 11).

Please note that:
- Your child's participation in this research is completely voluntary and will not disturb normal schooling period. It will be conducted between April/May 2013.
- Your child can withdraw from the research study at any time without penalty.
- No discomforts or risks are foreseen.
- The results of this participation will be confidential and kept completely anonymous, and will not be released in any individually identifiable form without the prior consent of yourself and your child, unless otherwise required by law.

Page **1** of **2**

- The report of the study will be accessible to parents, schools, Limpopo Department of Education and other organisations who might be interested in the research by application to the University of Pretoria.

NB: If you do not want your child to participate, please complete and return the attached consent form by the 5th of March 2013. If I don't receive this form, then I will assume your child can participate in the research pilot study.

If you would like further information, you can contact me on telephone 082 411 7054, fax 086 655 8442 or email eddybaloyi@ananzi.co.za or Supervisor Dr. Kazeni M.M.M at 012 420 5734.

Please keep the attached copy of this letter for your records.

Yours

…………………………………………

Baloyi H.E. (Researcher)

Consent Form

Please complete and return to your child's teacher by 5th March 2013 if you do not want your child to participate.

Name of child…………………………………………………………

Class…………………………………………………………………..

I **do not** want my child to participate in the research study on *The effectiveness of group practical investigations on learners' acquisition of integrated science process skills.*

Print name……………………………………………………

Signature………………………………………………………

Date……………………………………………………………

Please note: If I do not receive this form, I will assume that your child can participate in the research study.

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