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An examination of Grade 9 learners' process skills and their scientific investigation ability

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

This research study explored Grade 9 learners' process skills and their ability to conduct a scientific investigation. The understanding of these skills, for example observation, measurement and data collection, that these learners drew upon, and the way they reasoned while communicating their findings in the investigation, were also examined. This whole process was evaluated using three tools: a written survey, interviews, and observations of 42 Natural Sciences learners at the primary school. The written survey was the base-line tool to evaluate the learners' understanding of scientific investigation. The interviews were done in five categories: the purpose of scientific investigation, the role and the advantages of understanding process skills, the problems and challenges encountered when learners are performing scientific investigations and experiences gained in conducting a scientific investigation. The main body of data was obtained from observing learners working cooperatively in the actual process of conducting scientific investigations. An analysis of their performance of tasks, both individually and as part of the group, was conducted. An analysis of the sample of learners' performances revealed that few learners display a satisfactory understanding of how to collect data and communicate their findings. Instead, only a partial achievement of the requirements of conducting a scientific investigation was the norm. These learners observed and measured inaccurately, identified only some variables, established only simple trends in the process of collecting data, and did not form enough structure to communicate their findings.

Opsomming

Die prosevaardighede en die vermoë om ‘n wetenskaplike ondersoek uit te voer deur graad nege leerlinge, is ondersoek. Die begrip van hierdie vaardighede, byvoorbeeld waarneming, meting en data versameling, sowel as die beredenerings wyses tydens die oordrag van die bevindinge (resultate) van die ondersoek, is ook geëvalueer. Die proses in totaliteit is geëvalueer deur die gebruik van drie take insluitende geskrewe ondersoeke, onderhoude en waarnemings. Twee-en veertig Natuurwetenskap leerlinge van die primêre skool het aan die ondersoek deelgeneem. Die geskrewe ondersoek was die grondslag (fundamentele) aktiwiteit om die leerlinge se begrip van ‘n wetenskaplike ondersoek te evaluur. Die onderhoude was onderverdeel in vyf afdelings insluitende die doel, die belangrikheid, die voordele van die verstaan van prosesvaardighede, sowel as die probleme en uitdagings ondervind terwyl die leerlinge aktief betrokke was by of self besig was met die uitvoering van wetenskaplike ondersoeke. Die meerdeheid data (inligting) was verkry deur die waarneming van leerlinge wat saamwerk tydens die uitvoering van die ondersoekeie ondersoeke. ‘n Ontleding van die leerlinge se prestasie in die opdragte, individueel, sowel as in groep verband is gedoen. ‘n Ontleding van die leerlinge prestasie het getoon dat min leerlinge voldoende (bevredigende) begrip toon aangaande data (inligting) versameling en die oordra (kommunikasie) van die bevindinge (resultate). Die resultate van die ontleding onthul (toon) dat die gedeeltelike bereiking van die vereistes vir die uitvoering van ‘n wetenskaplike ondersoek die norm was. Hierdie leerlinge se waarnemings en meetings was onakkuraat, kon slegs sommige veranderlikes identifiseer, het slegs basiese wyses gebruik om die inligting (data) te versamel en te verwerk, en die oordrag (kommunikasie) van resultate was onvoldoende.

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CHAPTER ONE

Introduction

1.1 Background

Scientific investigations and process skills form part of the framework of the current curriculum in the Natural Sciences learning area in South African education. Learning in science can be improved through conceptual understanding and developing investigative skills (Department of Education (DoE), 2002: 13). This is imperative in providing innovative, creative, and scientifically literate citizens capable of competing nationally and globally (DoE, 2002: 1).

Teaching and learning science both involve the development of a range of process skills that may be used in everyday life, in the community, and in the workplace. Learners can gain these skills in an environment that supports creativity, responsibility and growing confidence. They develop the ability to think objectively and use a variety of forms of reasoning while they use process skills to investigate, reflect, analyse, synthesise and communicate (DoE, 2002: 4). According to Hassard (2007: "no page number") most learners in senior primary (Grades 8 and 9) or secondary schools (Grades 8 -12) should be able to exhibit these skills. Without the ability to observe, question, test and hypothesise, the learners have little chance of developing scientific understanding about any other concepts.

1.2 Rationale

Science is an important field of study for learners at school. As the National Curriculum Statement (NCS) points out, science plays an increasingly important role in the lives of people due to its influence on scientific and technological development, which underpins the economic growth and the social well-being of our community (DoE, 2003: 9). It has played a vital role in the past and will continue to play a significant role in the future.

Despite its great importance in our daily lives, however, there seems to be an idea prevalent that there are no good investigational tasks in the learning of science in school. Such a perception could be the result of the poor quality of the investigational advice given to learners. At the same time, it could be possible that learners are not exposed to such tasks.

Popularizing scientific investigational and process skills among the learners means disseminating research skills to an unsuspecting audience. That dissemination is a natural extension of efforts of scientists in writing journal articles and presenting conference papers. Scientists are the primary experts of their own research, but to ensure that their work reaches beyond narrow research groups, it must be communicated to others. The dissemination will help to convey to non-scientists and future scientists the inherent excitement and underlying goals of the science discipline.

Before learners can undertake research in science, they have to develop an understanding of the skills they need to apply in a given task. They also have to understand the steps to be followed in a scientific investigation, so that they may use them when conducting a series of scientific investigation tasks in the future. Furthermore, the investigational tasks are intended to raise the awareness of the learning outcome 1 (LO 1) and its importance in the Natural Sciences. The tasks are planned to give learners a taste of how to carry out a scientific investigation for themselves with a view to improving their own investigative skills.

Scientific investigation is an essential outcome for the learning of science, and learners therefore need to develop their own understanding before they can apply it in their classrooms. Below is an explanation of the purpose or the scope of inquiry for this study.

1.3 Statement of purpose

A learning outcome is a statement of the operations which a learner must be able to perform within a given range of scientific knowledge. Learning outcomes stress the learner’s ability to use science knowledge, not simply to acquire it. Using science knowledge refers to the learner’s ability to operate and work with knowledge, to recognize when an idea is relevant to a problem, and to combine relevant ideas. Progress in learning outcomes is reflected not solely in terms of the amount of knowledge a learner can recall. Rather, learning outcomes1 (LO 1), 2 (LO 2) and 3 (LO 3) are used to assess progress in the learner’s ability to plan and carry out investigations involving knowledge, and the ability to interpret and apply that knowledge in classroom situations as well as in situations affecting the learner as a member of a changing society (DoE, 2002: 6 - 7).

This study focused only on LO 1 in the learning area of Natural Sciences. LO 1 states that the learner will be able to act confidently in exploring his or her curiosity about natural phenomena, and able to investigate relationships and solve problems in scientific, technological and environmental contexts (DoE, 2002: 6). Assessment standards for this learning outcome involve planning investigations, conducting investigations, collecting data, evaluating data and communicating findings (DoE, 2002: 46). The assessment standards define the level at which the learner operates in an outcome (DoE, 2002: 7). Progress in this learning outcome is seen in terms of increasing competence in perceiving, describing and testing relationships between variables. The assessment standards reflect this increased growth in competence (DoE, 2002: 9).

Considering the importance of scientific investigation and process skills, this study intended to look carefully at the following question:

> Do Grade 9 learners in school X demonstrate the process skills of observing, measuring, collecting data and communicating their findings when conducting a scientific investigation?

To elaborate upon this: Do Grade 9 learners in school X understand process skills when they are involved in conducting a scientific investigation? (Can they observe, measure, collect data and communicate their findings?)

1.4 Brief overview of scientific investigation and process skills

A scientific investigation is an open-ended task that integrates science theory within the science discipline in order to encourage higher-order thinking (Lake, 2004: 110). Hattingh, Aldous & Rogan (2007: 77) referred to an open-ended task as representative of sophisticated learner-centered activities. In the four levels of complexity from 1-4 in science practical work they classified these tasks in level 4. They wrote,

> Learners design and do their own 'open-ended' investigations.
> Learners reflect on the quality of the design and data collected and make improvements when and where necessary.
> Learners can interpret data in support of competing theories or explanations.

Haefner & Zembal-Saul (2004: 1654) said that these tasks emphasise the learning of science as enquiry. This offers a problem in which there is no easily recalled solution and involves the use of both substantive and procedural ideas in a complex task or series of tasks, rather than as a particular problem to be solved (Roberts, 2004: 114 - 115).

A scientific investigation is a crucial window on the everyday world through which science can be seen in action. A scientific investigation can be a way of showing how experimental science has its roots in a careful, concept-driven view of the real world (Roberts, 2004: 114). In this perception, science is related to everyday life and affects all of us (Murray & Reiss, 2005: 92).

When learners are involved in a scientific investigation, therefore, they gain an insight into what science is all about (Murphy & Beggs, 2003: 113).

Scientific investigation also helps to show learners how they can develop their knowledge and skills by using apparatus (Morrison, 2005: 81). The apparatus provides an opportunity for them to participate in practical work and to promote good laboratory practices. It also offers learners a chance to experience the reality of a scientific research environment. Most importantly, the exercise should be a fun learning experience, comparatively free of the normal classroom restrictions (Earland, 2004: 69).

A scientific investigation is an inquiry treated as a process in which learners acquire such skills as observing, inferring and experimenting. Inquiry is central to science learning. When engaged in inquiry, learners describe objects, events, ask questions, construct explanations, test those explanations against their existing scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, they actively develop their understanding of science by combining scientific knowledge with reasoning skills (Haefner & Zembal-Saul, 2004: 1654).

Such an investigation benefits learners and helps them to acquire new skills such as the ones mentioned above. These skills provide meaning to the content that is relevant, updated and makes connections within their field of enquiry (Fogleman & Curran, 2008: 35). However, learners face enormous challenges in acquiring the content and process skills of science. In addition to the difficulty of the content, many learners struggle with the skills needed to be proficient readers and writers (Carnine & Carnine, 2004: 216). Both the teaching and learning of scientific investigation should therefore incorporate principles of instructional design that have been documented to improve comprehension of science content, process skills and higher-order thinking (Carnine & Carnine, 2004: 203).

Furthermore, involving learners in scientific investigation setups enables them to use a journal content approach for descriptive writing as well as for recording experiments, charts, graphs and other data. They can also include information about activities and experiments that they have conducted. The journal content serves as a forum for learners to ask questions, make predictions and form logical explanations (inferences) about their observations – what they see, hear, taste, touch and smell. In addition, they can include simple labeled drawings and sketches to help communicate their observations. As they progress through their investigations, they can sequentially build on previous knowledge and processes they have experienced first hand. They learn by doing. Eventually, they acquire the skills necessary to conduct their own original investigations (Harrell & Bailer, 2004: 35). Moreover, the experience gained enables them to learn important science concepts and also appreciate how scientific knowledge is generated (Haefner & Zembal-Saul, 2004: 1654 - 1655).

1.4.1 Effective teaching

The goals of teaching scientific investigation are described as an understanding of the nature of science, its modes of inquiry and conceptual inventions. Equally important are knowledge of natural phenomena and the place of science in the activity of man. These goals, however, have meaning only if taught in a related context and in a style appropriate to current needs (Hurd, 2000: 27).

If a learner is to maintain rapport with current needs and the changing face of science when he is no longer a learner, he will need to develop competencies and habits which will enable him to inquire for himself (Schwab, 2000: 26). The teaching of scientific investigation must give future scientists (learners) the chance to question science, to explore how scientists really work, and the freedom to discuss the aims of science (Tweats, 2006: 44). Future scientists should leave school with a deeper sense of the nature of scientific knowledge, including the way ideas are produced, evaluated and revised (Erduran, 2006: 45).

Investigation has a central place in science because it helps learners to understand how scientific ideas are developed and because the skills and process of scientific inquiry are useful in many everyday applications. Scientific investigation also provides opportunities for learners to consider the benefits and drawbacks of applications of science in technological developments, and in the environment, in health care, and in the quality of life (Tweats, 2006: 44). Therefore, an appropriate highly skilled science teaching is central to securing the necessary levels of science education for future scientists (Leach, Holman & Millar, 2005: 105).

In addition, the teachers of scientific investigation should always look for activities that encourage learners to think and act like scientists. Allowing them to practice ideas and concepts that define the nature of science helps them view scientific inquiry as a process. Learners gain insight into scientific inquiry when they design experiments that examine the behaviour of different objects (Vreeland, 2002: 36). In this way, they are acquainted with the process of inquiry as a means for exploring and developing ideas. Theories or models are needed to synthesize the data, tell whether the experiment meant anything, and describe the conditions which permit predictions (Hurd, 2000: 27).

Moreover the teaching of scientific investigation is essential to building opportunities for learners to talk through their own ideas and listen to the ideas of others (Staples & Heselden, 2002: 94). It also encourages them to express their science thinking in writing (Berber-Jimenez, Montelongo, Hernandez, Herter & Hosking, 2008: 61). Again, it helps them to acquire academic scientific language in several ways; writing and reading activities in particular provide the structure that learners need in academic tasks (Carlson, 2000: 49).

1.4.2 Learning

Learning about scientific investigation is a rewarding process because it encourages learners to be involved in projects and concepts they find interesting. At the same time, it helps them to formulate an explanation for the behaviour of their project, based on scientific understanding (Vreeland, 2002: 36 & 38). Learners enjoy the social aspect of the project, which in turn helps them to develop their own social skills. By working as groups they can come up with collective solutions, further encouraging them to be socially responsible (Murray & Reiss, 2005: 82). When learners are responsible, they will enhance both their enthusiasm and their scientific knowledge by performing a pivotal role in the project (Morrison, 2005: 77).

Scientific investigation stimulates learners because the solutions to the problems and the understanding of ideas in the work they are doing come from them rather than from their teachers (Hughes, 2004: 71). They do not simply copy work from the chalkboard and try to understand it later (Richardson, 2008: 97). Instead, they plan their work, design the investigation, record their results and draw their own conclusions (Hughes, 2004: 71).

Since learners have to plan, design, and record in order to draw conclusions, they need to read and write with a special vocabulary that communicates their learning and knowledge in the language required in science. This vocabulary will help them to gain the knowledge and skills needed to handle the increasing factual load in science content (Berber-Jimenez *et al.* 2008: 56). In addition, they have to understand the role of language in learning, including the importance of talking as a group to tease out and consolidate conceptual understanding (Probyn, 2004: 58).

1.5 Research design

Aim

This study aimed to evaluate and explore learners' process skills and scientific investigating abilities. The focus was the Natural Sciences in the senior phase, Grade 9 at school X, situated in Nyanga. Learners were supported in acquiring an understanding of science learning and in gaining a learner-centred perspective. They developed an understanding and participated in investigative activities involving process skills.

Through an intervention activity this study also actively supported and motivated learners to improve their knowledge and skills in scientific investigation. The intervention activity consisted of concept process skill development, together with the use of resources and learning support materials, e.g. the manual of how to conduct a scientific investigation (Gray, 2004: 19 - 20).

Data was obtained from three sources: written surveys, interviews, and observation of learners as they actively conducted scientific investigations.

The written survey was in the form of a base-line activity. This activity was to understand what learners perceived as a scientific investigation.

The main body of data was obtained from observation of the learners as they worked cooperatively in groups of four on a given task. The learners were from two different classes but were combined in one class when they were conducting scientific investigations. The class was large enough to accommodate the big group. The task they needed to perform was to conduct a scientific investigation. The observation which constituted the core data of this study captured the actual process, which involved observing, measuring, collecting data and communicating findings. The assessment tool was used to evaluate the competency level of the learners' process skills.

All the learners were interviewed on their views of a scientific investigation. The interviews were analysed in the following categories: the purpose of the investigation, the role and the advantage of understanding process skills, the problems and challenges encountered when learners were actively involved or performing the investigation and experiences gained in conducting a scientific investigation.

1.6 Participants

The research was conducted among Grade 9 learners at a primary school in Nyanga (Western Cape). The learners at this school were Xhosa speaking from more or less the same cultural background. The medium of instruction was English but some of the concepts were translated into Xhosa to facilitate a common understanding. More details of this will be discussed in Chapter 3, Research Methodology.

1.7 Procedure followed to collect data

The three instruments used were analysed in the following manner. Each instrument was analysed separately. The written survey, which was the base-line activity, was in the form of a questionnaire in which the learners wrote their responses individually. After this, they were observed participating in a hands-on activity, performing a scientific investigation in groups of four. When they had completed the investigation, they were interviewed in the same groups.

The analyses of each instrument are presented below. Method triangulation was used to combine these instruments. The reasons for choosing method triangulation will be discussed in Chapter 3, Research Methodology.

1.7.1 Written survey

The base-line activity was completed and submitted by 39 learners. The transcripts were analysed in five categories. Each category was analysed separately.

Category One was analysed in the following manner. The results were presented in a table that was divided into four columns. In the first column was the question asked in the questionnaire of the base-line activity. The second column recorded the responses from the learners. The third column was the group number of the members' responses. The fourth column was the summary of the learners' responses in percentages. The title of this category was `Survey relating to the learners' understanding of the scientific investigation'.

Category Two recorded the steps followed when carrying out the scientific investigation and was summarised in percentages. Category Three results were presented in a table that was divided into two columns. The subheadings of these columns were `Questions asked in the base-line activity' and `Responses of the learners in percentages'. This category was 'Survey relating to where and in what grades learners had carried out a scientific investigation before'.

The results for the fourth and fifth categories were presented in a table that was divided into two columns. The title of this category was `Survey relating to scientific investigation as a discipline'. The responses from the learners were summarised in percentages. Below is the analysis of the results for the second instrument, Observation.

1.7.2 Observation

Learners were observed and evaluated by means of an assessment rubric. The rubric was presented in a table and divided into four different assessment criteria. These in turn were categorized into four levels. The levels were further divided into two subsections to indicate and describe the achievement of the learners. They performed this activity in groups of four members, with a total of ten groups. Below is the analysis of the results for the third instrument used, the Interviews.

1.7.3 Interviews

Interviews were performed in two sessions. The results for the first session were not clear enough to be analysed. The interviews therefore had to be repeated for a second time, before being analysed. Learners were interviewed in the same groups, though some were absent from school on the day of the second interview. A number of groups were combined, reducing the total number of groups from ten to eight.

The interviews were analysed in five categories. The first category was `The purpose of carrying out a scientific investigation'. The second category was `The role of understanding process skills in scientific investigation'. The third category was `The advantages of understanding a scientific investigation'. The fourth category was `The problems and challenges encountered when conducting scientific investigation', and the fifth category was `The experiences gained in conducting a scientific investigation'.

1.8 Outline of how data was collected

Table1 presents the activities performed in this study and the period spent collecting data.

Table 1 How data was collected

Number of activities	Activities	Time-frame
1	Learners wrote base-line activity	One day (one hour per class)
2	Learners were taught how to conduct scientific investigation (learner development activity/ intervention activity)	Three days (three hours per class)
3	Learners carried out scientific investigation (observation)	Four days (four hours)
4	First session of the interviews	One day (two hours)
5	Second session of the interviews	One day (four hours)
6	Data analysis	One and half months

1.9 Chapter outline

Chapter One introduces the research of this study. This chapter provides the background, aim and the rationale for the study. The research question discussed required that learners display their process skills when conducting a scientific investigation. This chapter also gives a brief overview of the following chapters.

Chapter Two relates to the research of this study measured against recent findings in published literature. This chapter is therefore a tool that was utilized to compare existing findings with the findings from this research. The essential aim of this chapter was to establish the context of the topic.

Chapter Three discusses the method followed in collecting data in this study. The study used method triangulation, combining three instruments to collect data: the written survey, observation of learners carrying out a scientific investigation, and the interviews of learners. The step-by-step plan of how the study was conducted is explained in detail in this chapter. A detailed sequence of the events that happened when the data was collected is also provided.

Chapter Four discusses the details of how the data was presented and analysed. The results of this study are analysed in tables, accompanied by paragraphs which describe those tables and the other results. The analysis explains the results that were collected and recorded.

Chapter Five is the discussion of this study. This part of the study discusses how the findings fall within the conceptual framework of the literature that was discussed in this study.

Chapter Six is the last chapter and sums up the research findings, draws comparisons and offers data on the general problems of teaching science in South Africa. This chapter also outlines possible future areas of research.

CHAPTER TWO

Literature Review

2.1 Preliminary Study

Scientific investigation and process skills are activities that scientists execute when they study or investigate a problem, an issue or a question. These skills are used to generate and to form concepts. Process skills are the way of thinking, solving problems and developing ideas. This implies that thinking and reasoning are skills involved in investigative and learning strategies (Rambuda & Fraser, 2004: 10).

In Piaget's theory the earliest developmental stage in which thinking can be regarded as scientific is the formal operational stage (over age 14). At this age, learners are capable of operations such as drawing conclusions and constructing tests to evaluate hypotheses; in short, an expanded set of logical operations. The logical or formal operations, which are reasoning patterns, include theoretical reasoning, combinatorial reasoning, functional and proportional reasoning, control of variables, and probabilistic reasoning (Hassard, 2007: "no page number").

These reasoning patterns are important in carrying out investigations, as they are closely related to the concepts of evidence (Mbano, 2004: 106). Learners are involved in carrying out investigations when they do practical work which gives insight into scientific method and develops expertise in using it. They learn how to interpret data, to draw a sound conclusion, and to judge the level of confidence they have in their conclusion. They also learn how to design an investigation to answer inquiry questions or solve them (Hodson, 1990: 39).

Participation in hands-on investigative experiences and related activities helps learners discover answers to their scientific inquiry questions. They gain valuable experience in scientific practices while building their skills in mathematics and language, and also deepen their content understanding (Sutman, Schmuckler & Woodfield, 2008: x - xi). Answering inquiry questions is a multifaceted activity which involves making observations and reviewing what is already known in the light of experimental evidence, using tools to gather information and communicating the results. Inquiry also requires the identification of assumptions, the use of critical and logical thinking (higher-order thinking skills), and the consideration of alternative explanations (Hofstein & Lunetta, 2003: 30).

Furthermore, developing higher-order thinking and the skills needed for doing scientific investigations encourages learners to think about their own thinking (metacognition) and to reflect on and share their learning experiences (Mbano, 2004: 105). They begin to understand not only new concepts but also evolve a rationale for knowing them. Understanding the goals or outcomes becomes self-evident to the learners (Sutman *et al.* 2008: 14). They are made or directed to acquire knowledge, skills and attitudes by finding out things for themselves, with their teachers only acting as facilitators and resources (Alebiosu, 2005: 110).

Additional research has led to the conclusion that inquiry promotes critical or higher-order thinking skills and positive attitudes towards science. Teachers can, at the appropriate times, engage learners in inquiry investigations and satisfy their curiosity and desire for learning (Llewellyn, 2004: 10). Teachers are required to introduce and rehearse a new way of working which encourages the learners to be more independent (Johnson, Scholtz, Hodges & Botha, 2003: 93).

2.2 Learners' approach to scientific investigation and process skills

Scientific investigations enable learners to act confidently in exploring their curiosity about natural phenomena, and in investigating relationships and solving problems in scientific, technological and environmental contexts (DoE, 2002: 6). Increasing competence can be seen as the learner generates products and questionnaires, collects data, creates testable questions and fair tests of ideas, and explains conclusions. The learner shows initiative and puts his or her mind to practical problems, such as those of observing and measuring (DoE, 2002: 8).

The definition of assessment standards has been outlined in Chapter One, page 3. It anticipates that, by the end of Grade 9, the learner will be able to apply that knowledge to simple problem solving. The learner's imagination, curiosity and ability to ask questions will increase and broaden. His or her skill in doing practical work and evaluating investigations, or judging whether the investigation was a fair test of an idea, will also increase (DoE, 2002: 9).

As the learners carry out the procedures of their investigation, they must read instruments accurately, take an adequate number of trials, and organize data in logical and meaningful ways. They must also make detailed observations and transform raw data to reveal patterns, relationships between the variables, or clarify results. Through their investigation, they will generate numbers and descriptions which will be at the centre of their discussion about meanings (Hinrichsen & Jarrett, 1999: 10). They will be engaged in inductive and systematic thinking and verification of facts based upon a variety of useful and relevant prerequisite knowledge and competencies (Alebiosu, 2005: 110).

2.3 Research-based methods for teaching and learning scientific investigation and process skills

There are good reasons for using an investigational approach to science teaching, in addition to the pragmatic aspect of it presented in the National Curriculum. For many learners it can be a great motivator, particularly if they really become involved in a long-term investigation. Many learners who are not successful in, or motivated by, other aspects of science work, such as learning content or written work, can be turned on by and successful at investigational work. This can lead to teamwork and cooperation in science learning, which it may be difficult to develop quite so actively in other ways. Investigational work can also be extremely enjoyable, perhaps leading more learners to choose science once they reach the age of choice and consent (Wellington, Henderson, Lally, Scaife, Knutton & Nott, 1994: 142).

If learners are to gain an appreciation for science and choose to compete in the scientific and technically oriented society of the new millennium, they will need a curriculum that promotes active learning, that helps with problem solving, and that offers ways to answer questions (Llewellyn, 2004: 10). A science curriculum is more than just biology, chemistry and physics; there are many other avenues of science, including the investigational approach, that can be explored. Furthermore, there are many ways in which curriculum topics can be taught with an investigational approach that links to future careers or develops a scenario that highlights the learners' talents (Hannan, 2008: 125). An investigational approach to science that is inquiry-based is an effective means of enhancing scientific literacy (Llewellyn, 2004: 10). Instructional planning for inquiry-based science or discovery investigations should be approached with particular learning goals in mind. These usually include objectives for both content learning and inquiry or discovery skill development (Sutman *et al.* 2008: 14).

2.4 Factors affecting scientific investigation and process skills

a) Classroom and group organization

A typical science classroom looks different from the classrooms in which other subjects are taught, since student inquiry/discovery does not occur only in a laboratory setting or just during follow-up discussions. The classroom setting needs to constantly remind learners that a significant purpose of science education is to prepare them to inquire and discover (Sutman *et al.* 2008: 21). An important feature of the inquiry/discovery classroom is the resource centre where basic references, journals, and other print materials, including items from the Internet, are available. This encourages further independent discoveries. A single textbook should not be considered as the source of all information (Sutman *et al.* 2008: 22).

The major resources for use in inquiry/discovery-oriented science instruction, of course, are the formal and informal laboratory settings. Here learners discover answers to their inquiries through handling or manipulating both traditional and non-traditional scientific equipment and materials (Sutman *et al.* 2008: 22). They do this in an environment suitable for them to explore their knowledge of phenomena and construct related scientific concepts. The importance of a laboratory setting lies principally in providing learners with opportunities to engage in processes of investigation and inquiry in small groups (Hofstein & Lunetta, 2003: 29).

A learner-centred approach should be promoted in a science class, where small groups discuss their own ideas and reach conclusions from information provided (Johnson *et al.* 2003: 93). Group dynamics should be considered, since most investigations are carried out collectively. The active role of each group member is essential. Do all members of the group contribute equally or do some assume minor or subsidiary roles? Also, do they all learn equally or are some participating only in a clerical role, with little or no understanding of the underlying principles? When plans are produced individually, whose plan is followed in a group (Wellington *et al.* 1994: 142)?

b) Facilitation or teaching style

Scientific investigations and process skills can be seen as the building blocks from which suitable science tasks are constructed. This framework enables teachers to design the tasks and formulate questions which promote critical thinking (DoE, 2002: 13). The teachers are in the best position to decide the sequencing of ideas, as well as when and how they should be taught in their class (Roberts, 2004: 119). They have to mediate the cognitive conflict by breaking the task into smaller, manageable units for the learners. They also have to help learners on relevant aspects of the task (Mbano, 2004: 106).

Furthermore, to guide teaching and learning, it is important for both teachers and learners to be explicit about the general and specific purposes of what they are doing in the classroom. Explicating goals for specific learning outcomes should serve as a principal basis upon which teachers design and use tasks. The goals can also serve as the most important basis for the assessment of learners and of the curriculum and teaching strategies. To these ends, it is important to acquire information and insight about what is really happening when learners engage in investigative tasks (Hofstein & Lunetta, 2003: 38).

However, certain critics of the investigational approach argue that it will leave less time for content, but this need not be the case. On the contrary, it could provide the motivation for learning content (Wellington *et al.* 1994: 143). For many teachers of science, the introduction of an investigational approach can entirely change the way they approach the teaching of science generally. This means that the teaching of content (conceptual understanding) and process skills (procedural understanding) can be geared entirely towards an investigational approach as the end point or motivator (Wellington *et al.* 1994: 142).

In the investigational approach, teachers are often encouraged to restructure their presentations to reduce lecturing and to focus only upon asking their learners questions. Instead, they should open the door for their learners to inquire and discover for themselves. The teacher should provide guidance and encouragement, at least until learners return to what was once a natural and useful habit (Sutman *et al.* 2008: 4). The teacher must move away from the blackboard and from a role as dispenser of wisdom. For many teachers this is a radical step away from their past practice, which tended to be entirely `chalk and talk'. The teacher should organize the learners' discussions and manage group work and feedback in a way that leads to the whole class reaching a closure for the task (Johnson *et al.* 2003: 87).

It is equally important in the investigational approach that teachers use the available apparatus and equipment with their learners. Without an understanding of why this is so important in science education, the teachers will not have the enthusiasm needed to work with their learners (Richardson, 2008: 105). The teachers need to give learners an opportunity to explore at first hand, so that they can make generalizations and determine principles for themselves (Alebiosu, 2005: 110). Learners should also be given significantly more opportunities for involvement and initiative (Sutman *et al.* 2008: 17). This will help to enhance their investigative skills. Effective learners operate best when they have insights into their own strengths and weaknesses and access to their own repertoires of learning (Mbano, 2004: 106).

c) Task design

Scientific investigations are a core component of science curricula. These investigations are referred to as scientific problems or tasks that require learners to record findings, draw conclusions and report their results. The aim of such tasks is to enable them to learn to do as scientists do (Mbano, 2004: 105). Scientists carry out investigations, including practical experiments, when considering problems for which there are no easily recalled solutions. These investigations use both substantive concepts and procedural ideas in a complex task or series of tasks rather than solving a particular focused problem. They allow learners to be creative while they recall skills and modify protocols with which they are familiar. They also invent new ways to solve practical problems, apply new contexts and synthesise the substantive and procedural ideas to solve problems and analyse the data to evaluate the evidence (Roberts, 2004: 115).

Furthermore, scientific investigations are designed to be used effectively by learners with different levels of relevant knowledge and with different cognitive abilities (Hofstein & Lunetta, 2003: 37). Scientific investigations interact closely with the learners' prior knowledge and understanding and cannot therefore be separated from them. This has an implication for the type of investigation that the learners can be expected to carry out and is important when considering progression and assessment (Wellington *et al.* 1994: 143).

Examples of such cases are investigations followed by discussions and further exploration and discovery. These investigations are necessary if learners are to acquire the focus and concentration needed both to increase content understanding and to develop sophisticated scientific thinking skills (Sutman *et al.* 2008: 33).

CHAPTER THREE

Research Methodology

A qualitative study of primary school learners was done to answer the research question. The learners who took part in this research were doing Natural Sciences as a learning area taught at their school. Learning Outcome 1 in Natural Sciences requires learners to be taught and to learn in an investigational and process skills approach (DoE, 2002: 8 - 9). The purpose of this study, therefore, was to investigate whether the learners in this school demonstrated the process skills of observing, measuring, collecting and communicating data when conducting a scientific investigation. The research question was answered with the help of the test instruments utilized below. These test instruments were administered and completed in September, 2008.

A qualitative study refers to any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification (Golafshani, 2003: 600). This study is in the form of words rather than numbers. Its data were gathered by observation, interviews and a questionnaire/survey (Zulkardi, 2009: 5). This kind of research produces findings derived from real-world settings in which the phenomenon of interest unfolds naturally (Golafshani, 2003: 600).

The aim of this particular qualitative research was to study Grade 9 learners in their natural setting. To this end, the researcher went out the learners' setting to gather the data (Creswell, 1998: 17). To achieve as accurate a picture as possible, she needed to collect data using different methods, including "methodological triangulation". In this approach, the researcher seeks to check the validity of her findings by cross-checking them with another method, offering an enhanced confidence in the results and conclusions (Bryman, 2009: 1 - 3).

3.1. Test Instruments

Method triangulation was used to combine three instruments which were designed to collect data in this study. These instruments were written surveys, interviews, and the observation of learners actively conducting scientific investigations.

3.1.1. The use of Triangulation

McGloin (2008: 51) refers to triangulation as a strategy to assess the truth value of a study. Through triangulation, multiple sources of data are used to enhance the credibility of the strategy. These sources include instruments or methods such as survey, observation and interview. Cohen and Manion (1980: 208 - 209) also describe triangulation as the use of two or more methods of data collection in the investigation of some aspect of human behaviour. They claim that the advantage of using triangulation is in overcoming the problem of "method-boundendness", since a single method/instrument offers only a limited view of the complexity of human behaviour and of situations in which human beings interact.

In this study, triangulation was carried out through the combination of three instruments, the written survey, observation of learners carrying out a scientific investigation, and the interviews. It was used to evaluate the subjects, the Grade 9 learners, from the different perspectives that were provided by the three instruments used (Nieman, Nieman, Brazell, van Staden, Heyns & deWet, 2000: 284). Triangulation was also used to map out or explain more fully the richness and complexity of the Grade 9 learners' process skills and their scientific investigative ability, again by studying them from more than one standpoint (Cohen & Manion, 1980: 208). In short, triangulation was a way to assemble the findings through seeing and hearing multiple instances from the different sources, using different methods/instruments (Miles & Huberman, 1994: 267).

According to Livesey (2009: 5), a combination of different methods/instruments will give a much more rounded picture of someone's life or behaviour. These different instruments are a strategy or test for improving the validity and the reliability of this research (Golafshani, 2003: 603). With the notion of combining these multiple methods, the researcher hoped to overcome the weakness or intrinsic biases and the problems that can come from using a single method (Zulkardi, 2009: 1). She believed that it could strengthen the validity of the study (Golafshani, 2003: 603).

3.1.1.1 Written survey

In this research, it was crucial to determine the learners' perceptions and understanding of process skills and scientific investigation. These were evaluated by means of a detailed written survey, in the form of a questionnaire (see Appendix A.1). A questionnaire is a measure of what people say they believe, not necessarily what they actually believe or want or do (Pillay & Sanders, 2002: 327). In it, the responedent is required to record his responses to each question or set of questions (Cohen & Manion, 1980: 241 and Gall, Borg & Gall, 1996: 289).

The set questions in this survey were open questions which enabled the respondents (learners) to write free responses in their own terms, to explain and qualify their responses, and to avoid the limitations of pre-set categories of responses (Cohen, Manion & Morrison, 2000: 248). These set questions were designed to invite an honest personal comment from the learners (Cohen *et al.* 2000: 255). Responses should be free of coercion, since questionnaires cannot probe deeply into respondents' opinions and feelings (Gall *et al.* 1996: 289).

In this study, the written survey was in the form of a questionnaire, which was the base-line activity used to establish what the learners perceived as a scientific investigation. They were given the base-line activity scripts with questions to answer. The researcher read the script aloud to the class, explaining each question in English and translating some words in Xhosa. Learners were asked to read their scripts quietly and to answer questions individually. They were instructed to raise their hands and ask if there was something they did not understand in the script, since at this stage they were not supposed to discuss anything as a group. They were also given an instruction to ask and answer in a language of their choice.

The following instruction was given on the base-line activity: `Please complete the following questionnaire.' Below this instruction was the following statement, giving the learners the reason why they needed to perform this scientific investigation: `One of the main skills that learners acquire in order to understand science is to learn how to carry out a scientific investigation.'

Below this statement were the questions to be answered. The questions in the base-line activity were designed around five broad categories: understanding a scientific investigation; the steps that must be followed when carrying out a scientific investigation; ascertaining whether the learners have carried out a scientific investigation before, and if so where and in what grade; establishing why Natural Sciences help learners to have a better understanding of situations in everyday life; and finding out which learners thought that a scientific investigation had little relation to their everyday experiences of the world and why.

3.1.1.2 Observations

As noted above by Pillay and Sanders (2002), when respondents are answering a questionnaire, they tend to say what they think they believe, not what they actually believe. It was therefore necessary for this researcher to have another means to measure and evaluate the understanding of these learners. The learners were observed while they were actively involved in conducting a scientific investigation. The purpose of the observation was to probe deeply and to analyse intensively the multifarious phenomena which constitute the life experience of these learners with a view to establishing generalisations about their behaviour (Cohen & Manion, 1980: 99).

While observing the learners, the researcher was able to discern ongoing behaviour as it occurred so that she could make appropriate notes about the salient features of that behaviour (Cohen & Manion, 1980: 103). She was given the opportunity to gather her data from live situations, with sufficient time to look at what was taking place in the situation, rather than assessing it at second hand (Cohen *et al.* 2000: 305).

At the same time, because the observation took place over an extended period of time, the researcher was able to develop a more intimate and informal relationship with the learners, giving her a better insight into their behaviour (Cohen & Manion, 1980:104). She was accepted as an insider by the learners, rather than being seen as a complete outsider (Creswell, 1998: 123). As an insider, she was able to formulate her own version of what was occurring, independently of the learners (Gall *et al.* 1996: 344).

In this research, the main body of data was obtained from observation of the learners working cooperatively in groups of four on a given task. The learners were in two different classrooms but had a common body of knowledge since they were taught by the same teacher. The task they needed to perform was to conduct a scientific investigation. The observation which constituted the core data of this study captured the actual process, which involved observation, measuring, collecting data and communicating findings.

The learners were taught how to conduct a scientific investigation before they were actively involved in the one they were expected to carry out. This was necessary, since it was found that fifty-one percent of the learners did not know the steps to be followed when carrying out a scientific investigation. The other forty-nine percent had an idea of some of the steps but could not identify them all. The learners were supported and motivated in improving their knowledge and the skills needed to conduct such an investigation. The researcher had designed a manual, and this was used as a model to assist the learners in their intervention activity. This manual or resource/support material gave guidelines on how to conduct a scientific investigation. It laid out all the steps for conducting such an investigation, including the title or heading of the investigation, the names and the grades of the learners conducting it, the problem, method, results, discussion, conclusion and acknowledgements (see Appendix B).

The learning cycle was initiated by a class discussion, with the researcher facilitating this intervention activity. The focus of this intervention was to show the learners how a scientific investigation is conducted. They were asked some of the questions from the base-line activity and on their ideas about a scientific investigation. As a result of this discussion a hypothesis was propounded. Following the discussion, the learners worked in small groups of four to identify lines of evidence that could support or reject their hypothesis. They were provided with the support material to assist them, discussing and reviewing their hypothesis with the help of the manual. They were also given an oral instruction to discuss each step and paraphrase the manual to confirm their understanding of the different stages of the project. These discussions gave the researcher the opportunity to monitor learners' understanding and to prepare an appropriate scaffolding of their knowledge.

The learners were also encouraged to do a critical appreciation of the manual. Using what they read in the manual, they had to write a summary of what they needed to do in each step. At the conclusion of the group discussions, each group had to report back to the class as a whole. During this, the learners' discussions were summarised. Each step from the manual was explained in detail by the facilitator/researcher. The learners were encouraged to apply the knowledge gained in this instructional sequence to the required task. Appendix B gives all the information they needed to complete the task (support material/manual). The outcome of this activity was to convince, assist and show learners how scientists conduct investigations. It took three days for this part to be finished because the Natural Sciences period in this school was one hour long.

The next day learners were given a case study to read (see Appendix A2). The theme for the case study was Energy and Change. The topic was the efficient and economic use of energy sources. The case study was divided into three paragraphs. The first paragraph was on the number of energy sources used in South Africa. The second paragraph was on how one specific family conserved energy. The third paragraph described the shutdown that happened when this family was in the house one evening. The mother of this family wondered which candle would cost less while her son was scrambling for candles to provide light in the house.

This boy decided to carry out an investigation about his mother's question. The learners were asked to conduct this boy's investigation. They were given six questions to guide and assist them in their discussions (see Appendix A2). The six questions were about the problem to be solved in the investigation, the hypothesis, the variables, the method, and the data. The learners were asked not to answer these questions but rather to conduct a scientific investigation on the basis of the questions. They were given tools to be used in conducting the investigation. These were three different sizes of candles, a watch, a ruler, matches and a piece of string. They were supposed to conduct this investigation in three to four hours. In the event, it was carried out in one hour per day over four days, as outlined above.

An assessment tool was used to assess learners both while they were conducting their investigations in groups of four and after they had completed the investigations (see Appendix A3). After they had finished with the activity, they were asked to submit their scripts to the researcher. They were given two A3 sheets on which to write their data, and one A3 sheet on which to scribble their ideas while they were busy discussing. The assessment tool was the rubric used by the researcher to evaluate the level of the learners' process skills. The researcher observed all the groups and also observed learners' discussions and performances using the assessment tool. The tool was divided into four different assessment criteria, which were categorized as follows: observing, measuring, collecting data, and communicating findings. Four levels from the criteria were used to assess the learners' scripts and performance. The criteria were divided into levels 1 – 4. Level 1 was the lowest assessment score/rate, indicating that the learners had found it impossible to perform the tasks, and level 4 was the highest assessment score/rate, meaning that learners exceeded expectations in performing their tasks.

3.1.1.3 Interviews

To avoid the weakness inherent in using a single method, a combination of different methods was used; this gave a more rounded picture of these learners, as suggested above by Livesey (2009). Interview was another tool, used as an auxiliary method in conjunction with the written survey and the observations. The purpose of this interview was to go deeper into the motivations of the learners and their reasons for responding as they did (Cohen *et al.* 2000: 268). The interview was an important tool for data gathering, with the researcher herself acting as a measuring instrument (Botha, 2001: 13). Being able to draw on evidence from an interview as an integrated whole allowed the researcher to gain a better understanding of the context in which a particular discourse was deployed (Brendan, O'Rourke & Pitt, 2007: "no page number").

The interview involved gathering data through direct verbal interaction between the researcher and the interviewee (Cohen & Manion, 1980: 241). Since interviews are verbal reports only, they are often subject to problems of bias, poor recall, and of poor or inaccurate articulation. These problems could beset a researcher as well. To avoid misinterpretation of what is said in an interview, a tape recorder may be used. This allows the researcher to make eye contact with the interviewee and to focus on his or her body language (Raitt, 2004: 66). However, due to unforeseen circumstances in the interviews in this particular study, the responses could not be tape recorded; the reasons for this will be discussed below. As a result, only written responses were recorded while interviewing.

Interviews may be tape recorded, of course, with the permission of the interviewee. Using a tape recorder has the advantage that it is more accurate than written notes taken down during the interview. However, tape recording also brings with it the danger that the interviewer may be tempted not to take any notes during the interview. Taking notes is important, even if the interview is tape recorded. It allows one to check if all the questions have been answered. It also provides a back-up in case of malfunctioning of the tape recorder, as happened in this study, or in the case of malfunctioning of the interviewer (Opdenakker, 2006: "no page number").

In this study the interviews were conducted in two sessions.

<u>Session one</u>

All the learners were interviewed about their views in the groups they were in when they conducted the scientific investigation activity. They were given scripts with interview questions to refer to when they were asked questions. They were interviewed orally in groups in order to save time. They were encouraged to answer the questions randomly, allowing any member of the group to display individual understanding and participation. Each of the interview questions was explained, so as to clarify any concerns from the learners. For example, some of the learners asked that some of the questions be paraphrased. This resulted in questions being asked in English and Xhosa; the learners were told that they could respond in either of these languages. They responded orally, then wrote their answers on an A3 page, handing it in when they had finished.

Session two

When the first session of interviews was examined, it was evident that further analysis could not take place because the responses were unintelligible. The second session of the interviews was conducted successfully; however, the audio-recordings that were planned could not be captured. The tape recorder was working well but could not record the audiotape. The process of finding out the problem with the tape recorder took longer than expected, and a decision was taken to concentrate instead on a written record of the responses from the learners while interviewing. As a result of this, the interviews took longer than the scheduled time.

More time was requested from the science teacher and the teachers of the other learning areas, who were asked to release groups of learners when they were needed for the interviews. This process took two hours of the scheduled time and another two hours of extended time. The same procedure as for the first session was followed, except that in this session the responses were written down by the researcher. This meant that the interviews scheduled were now in the following categories: the purpose and the role of process skills, the advantage of understanding, the problems and challenges encountered when learners are actively involved in performing a scientific investigation and the experiences gained in conducting a scientific investigation.

3.2 Participants

The participants comprised Grade 9 Natural Sciences learners from a township primary school in Nyanga, in the Western Cape, near the city of Cape Town. The learners in this school were Xhosa speaking from more or less the same cultural background. The medium of instruction was English. Some of the English concepts were translated into Xhosa to help everybody develop a common understanding. This sample of learners undertook three of the abovementioned tasks both as groups and individually in two classrooms made available for the research. These learners were 14 -16 year-old boys and girls in each classroom. The total number of participants was 42, of whom 13 (thirty-one percent) were female and 29 (sixty-nine percent) were males. Learners were divided into groups of four to perform the interviews and the actual investigation activities. Some groups were mixed groups of boys and girls, while some were only girls or boys; also, the groups were randomly assigned.

The learners sat at their desks, facing each other in their groups. They were taught science in their classrooms because there was no science laboratory in the school. The few pieces of equipment used by people who came to assist the school in science were kept in a cupboard in a Technology laboratory. Lecturing and the use of textbooks seemed to be the only teaching methods used. A maximum of two Natural Sciences classes per grade in the senior phase had two teachers for the whole phase. One teacher taught Grade 7 and the other taught Grades 8 and 9. They also taught other learning areas, with a maximum of four per teacher. It should also be noted that these two teachers did not major in science in their teacher training. This meant that learners' exposure to science process skills as the basis of senior primary or junior secondary school science was limited.

3.3. Validity and Reliability

A qualitative study was chosen to eliminate the casual errors that might influence the results of this research (Nieman *et al.* 2000: 284). In a qualitative study, validity can be addressed through the honesty, depth, richness and scope of data achieved (Cohen *et al.* 2000: 104). The method of triangulation was used as an alternative tool for validation, to add richness, depth, rigour, breadth and complexity to this study (Jaya, 2003: 73). It was also important to such a qualitative study to provide a clear, detailed and in-depth description of the project. Such a description could assist other researchers in deciding the extent to which the findings from this research were generalizable to another situation (Cohen *et al.* 2000: 109).

Furthermore, reliability in a qualitative study strives for replication in generating, refining, comparing and validating constructs, but this should include stability of observations. Through observations, reliability can be regarded as a fit between what the researcher records as data and what actually occurs in the natural setting that is researched (Cohen *et al.* 2000: 119). As suggested by Livesey (2009) and McGloin (2008) in the discussion of triangulation, the combination of different methods in this study was used as a strategy or test for improving validity and reliability, both to assess the truth value of the study and to enhance the credibility of the strategy.

Since this qualitative study took place in the real social world that was School X, it could well have real consequences in the learners' lives (Miles & Huberman, 1994: 277). A researcher should endeavour to do the research thoroughly and carefully (Finlay & Ballinger, 2006: 238). He or she should ensure that the truth value of the findings is attained, especially as the research is carried out in a real-life situation (McGloin, 2008: 50).

3.3.1. Validity as credibility and authenticity

Validity is a process of preparing a comprehensive register of data and notes of relevant actions or events, to be used during data analysis, and to establish audit trails that could be used to make corrections to content and concepts formed in qualitative research. Validity is also a provision of a 'thick description' of research as a way of enabling others to judge the results and their usefulness in other situations (Nieman *et al.* 2000: 285). Chapters 3.1 and 3.2 of this document describe and produce a rich, thick description to validate this research. This description aims to demonstrate the credibility of this research (Finlay & Ballinger, 2006: 239).

Moreover, when the researcher conducts a research study, she/he should ask her/himself whether the findings of the study make sense and whether the results are credible both to the people they study and to their readers (Miles & Huberman, 1994: 278). The researcher should view the emphasis on validity as a process of checking, questioning and theorizing, not as a strategy for establishing rule-based correspondences between the findings and the real world. The researcher should see validity as authenticity, where she/he should look for an authentic portrait in her/his research (Miles & Huberman, 1994: 279).

Authenticity is the hallmark of a trustworthy and rigorous inquiry, and it includes fairness. Fairness is seen as the quality of balance, so that all stakeholders' views, perspectives and voices are apparent in the text (Jaya, 2003: 78, cited Guba & Lincoln, 1989, 1994, 2000). This research study includes the perspectives and voices of all the participants, as displayed in Chapters 3.1, 3.2 and 4 of this document.

3.3.2. Reliability as dependability and auditability

Reliability in qualitative study is referred to as a quality concept that has the purpose of generating understanding (Golafshani, 2003: 601). In generating understanding, the researcher should consider whether the process of the study is consistent, reasonably stable over time as well as across the work of other researchers and methods (Miles & Huberman, 1994: 278). The point is that consistency belongs to the order of meanings, yet the desire seems to be expressed in the order of existence (Giorgi, 2002: 3). Consistency relates to the notion of dependability and is assessed through the use of an audit trail (auditability) to ensure accurate data collection (McGloin, 2008: 52).

Auditability is the preservation of all information regarding the research so that the findings could be verified by independent persons (Nieman *et al.* 2000: 284). It is a process in which the researcher demonstrates how her/his work and thinking progressed throughout the project with the use of verifiable documents (Finlay & Ballinger, 2006: 239). These verifiable documents should be established, trackable and documented. This study had shown auditability through method triangulation. This was used to increase reliability and to exhibit the detail that was required for dependability, so that other researchers could use the original report as an operating manual by which to replicate the study (Jaya, 2003: 78).

3.4. Ethical Clearance

The study was carried out with the permission of Western Cape Education Department (WCED). Permission was also obtained from parents, the science teacher and the Principal of the school for their learners to take part in this research. All the above-mentioned people, together with the learners, were given full knowledge of the purpose, nature and duration of the study. Pseudonyms were used in this study to ensure anonymity (Kanari & Millar, 2004: 753). Appendix C has the information about the confirmation of the permission from the WCED.

CHAPTER FOUR

Data presentation and analysis

4.1 Written Survey

4.1.1 The base-line activity

The base-line activity was administered to 42 learners. The learners actively participated for an hour during the time of the research at School X. Thirty-nine learners completed and submitted the base-line activity. The transcripts were analysed by summarising the sequence in the learners' perception of the scientific investigations. The questions in the base-line activity were designed around five broad categories. These categories were tabulated and summarised to describe the sequence in the learners' responses. This was done to capture the sequence of their thought processes (Mbano, 2004: 109).

The findings

The results in the first category are presented in Table 2. The learners are grouped together (Groups 1-3) according to their responses. The percentages from the learners' responses are also recorded. The first response categorizes those learners who saw scientific investigation as something that would help them to know more about the world around them, while the second response included those who equated scientific investigation with research. The last response was for those learners who did not have a direct answer to the question that was asked.

Table 2 Survey item relating to the learners' understanding of scientific investigations

Question	**Learner's Response**	**Group**	**Percentage (%)**
What is your understanding of a scientific investigation?	Something that one wants to know about the world around us.	1	15
	It is research.	2	26
	Learners had no direct answer.	3	59

Only six learners in Group 1 understood what a scientific investigation was. According to the South African Oxford Dictionary, the word 'investigate' is defined as finding out as much as you can about something or making a systematic inquiry. The responses were summarised and edited to come up with the results recorded in Table 2.

Here are examples of the original responses from three of these six learners.

Learner 1: "I think scientific investigation is something that you envestigate to know it better."
Learner 2: "My understanding about investigate scientific, I think is to know how you investigate something you don't know, but you need to know it."
Learner 3: "My understanding is to know what really happens in my world so that I can make a investigation and I get more knowledge."

In Group 2, only ten learners explained their understanding of a scientific investigation as research a person needed to conduct.

Here are examples of the original responses from three of these ten learners.

Learner 1: “Scientific investigation is when you research about a thing like a boomgate or is when you go out of a school or in the school you want to now about the thing that you don’t now.”
Learner 2: “I understand that investigation is something that you ask when you have research or assignment.”
Learner 3: “I think the scientific investigation is a research or is something that go out and also do a research.”

In this study, Groups 1 and 2 could not be combined because the researcher was not sure whether the learners understood the meaning of the word `research’; according to the definitions in the dictionaries the words ‘investigate’ and `research’ have the same meaning.

Group 3 learners did not have a direct answer to this question. These twenty-three learners did not know how to respond to this question. They did answer the question but wrote irrelevant responses.

Here are examples of the original responses from the three of these twenty-three learners.

Learner 1: “I understand if scientific investigation it is true and it is a investigation about science/scientific and it is based to general knowledge because most of the things are normal.”
Learner 2: “I think about scientific investigation we use the knowledge of yourself. They we going to take an more of knowledge. To take a care of investigation.”
Learner 3: “My understanding with scientific investigation is to go in a stage to go investigate what you want to investigate.”

Despite the learners having difficulties with English, and a significant desire to code switch, there was evidence that they wanted to express themselves in English. Only two learners in this group responded in Xhosa. Even though these learners answered in Xhosa, they did not respond well to this question. The linguistic barrier prevented the researcher from understanding clearly what the learners were trying to express. The responses were unhelpful in that the learners gave a lot of insignificant information while insisting on expressing themselves in English.

The results in the second category are summarised as follows:

Survey item relating to the steps that must be followed when carrying out a scientific investigation.

In this question, two learners (five percent) did not respond at all. A further five percent confused the steps needed to carry out a scientific investigation with those of a crime investigation. Their responses clearly described a crime investigation in which detectives were trying to solve a mystery or a problem. Points they mentioned including taking down names and asking about the place where an accident or a robbery happened. Fifteen learners (thirty-five percent) responded to the question but their responses added nothing. The researcher could not make sense of what these learners wrote.

However, nineteen learners (forty-nine percent) had an idea of what a scientific investigation was. They mentioned that the first step is to find out everything there is to know about the problem you need to solve. They said they had discovered information by talking to people and reading as much as they could about the problem. They also said they needed to visit libraries to get as much information as possible about the subject.

The responses of these learners show that they knew some of the steps to be followed in a scientific investigation. This helped them to understand something about the project they would be working on. It gave them clues to the kind of tools they might be able to use to solve the problem. It stimulated them to think, and to come up with a reasoned guess about how to solve the problem or what the solution might be.

Nevertheless, none of the learners in their responses mentioned their understanding of an hypothesis, or of a plan to carry out the investigation, ways of recording the data, of analysing the information, or of drawing a conclusion. Although the learners did not mention these steps, one learner did relate the steps to be followed in a scientific investigation to the ones in the Technology learning area. Described as the design process, these steps are to investigate, design, make and evaluate.

The results in the third category are presented in Table 3. Again, the learners' responses are summarised as percentages.

Table 3 Survey item relating where and in what grades learners had carried out scientific investigations before

Question	**Responses in percentages (%)**				
Did you carry out a scientific investigation before?	Yes				No
	82				18
Where?	MRC	Other school	Library	School X	
	15	18	5	44	
In what grade?	Grade 6	Grade 7	Grade 8	Grade 9	
	3	10	13	56	

All the learners responded to this question. Thirty-two learners (eighty-two percent) agreed that they had carried out a scientific investigation before, while seven learners (eighteen percent) had not. The eighty-two percent had carried out these investigations in different places. Six learners (fifteen percent) had conducted scientific investigations at the Medical Research Centre (MRC), seven learners (eighteen percent) at their previous schools, two learners (five percent) at the library, and seventeen learners (forty-four) at their current school (School X). They had performed these scientific investigations in different grades as indicated in Table 3.

The results in the fourth and fifth categories are presented in Table 4. The learners' responses are summarised as percentages.

Table 4 Survey item relating to scientific investigations as a discipline

Statement	Responses in percentages (%)	
Natural Sciences should help me better understand situations in everyday life.	Yes	No
	100	0
I think to understand a scientific investigation has little relation to what I experience in the everyday world.	Yes	No
	86	13

All the learners agreed that the Natural Sciences helped to give them a better understanding of situations in everyday life. They motivated this statement by enumerating different things they had learnt in Natural Sciences, for example, about pollution in environmental science, human science, plants and earth science.

Thirty-four learners agreed that understanding scientific investigations had little relation to what they experienced in the everyday world. They supported this statement by saying that science is only one of the learning areas that tell them about what is happening in the world. They also said they needed research to get information that could help them to understand the world. One learner did not respond at all to this statement. Five learners did not agree at all, but the motivations implied in their responses supported the statement. The phrase “little relation” confused the learners because they claimed that they learn more in science and in a scientific investigation. The section that follows examines the variation in the learners’ success rates when conducting a scientific investigation.

4.2 Observation

4.2.1 The assessment tool

The assessment tool was used to evaluate the competency level of the learners’ process skills when conducting a scientific investigation. This instrument was used during and after the learners had finished carrying out their projects. They performed the investigations in groups of four. The assessment tool was used in conjunction with the learners’ discussions and performances. The tool was tabulated and divided into four different assessment criteria.

The assessment criteria were categorised into four levels. These levels were further divided to record the evaluation of learners’ performances in more detail. The analysis of how they performed in their groups was also discussed. They performed in a total of ten groups. The average number of the groups’ performances per level was also indicated in the table. Appendix A.3 shows how the criteria and the categorised levels were compiled in the assessment instrument. This instrument will be explained and analysed in greater detail in the next subsection, the observation discussions.

The results of the criteria and categorised levels are presented in Table 5. The learners’ group responses are also analysed below the table.

Table 5 The evaluation of the learners' performances

Assessment Criteria	Level		Level		Level		Level	Total
Level division	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	
Level description	**0 - 34% Not achieved**		**35 – 49% Partial achievement**		**50 – 69% Satisfactory achievement**		**70 % & more Excellent achievement**	
Make accurate observations and measurements		2	6	2				10
Identifies whether it is a fair test			8	2				10
Collects the data	1	1	5	1	1	1		10
Communicates the findings	2	1	5		1	1		10
Average no. of groups/level	**2**		**7**		**1**		**0**	**10**

Make accurate observations and measurements

None of the learners perfectly fitted level 1 because they were all partially able to observe and measure. Two groups observed some variables, but measured incorrectly and were rated one and a half. Also six groups observed some variables, but some of their measurements were incorrect, so they were rated two. In addition, two groups were rated two and a half because they observed some but not all the variables, but measured correctly.

Identifies whether it is a fair test

Eight groups were rated two because they identified only a few variables. At the same time, two groups rated two and a half on identifying a fair test because they saw the wind blow through their classroom and realized that could affect their investigation.

Collects the data

One group only drew a table without understanding what they should write in it, and were rated one. Another group only drew an unfinished table correctly and rated one and a half. In the same way, five groups drew tables correctly and were rated two. One group was rated two and a half because they drew tables and graphs, while another one added a diagram to be rated three. The last group met the requirements of collecting data correctly and was rated three and a half.

Communicates the findings

Two groups were rated level one and another group was rated level one and a half because their work was incoherent, only partly structured, missed many steps, and had irrelevant interpretations. Also five groups were rated two because the accepted structure had been given some irrelevant interpretations. Level three was given to one group that had a coherent structure but missed one step, the conclusion. Lastly, one group was rated three and a half because on their graph the values on the axes were not kept constant.

4.2.2 The observation discussions

The learners were observed using the structured assessment tool. Each group was observed randomly to view their understanding of the task provided. The observations were divided into the four criteria used in the assessment tool. The interpretable answers and discussions were compared to the assessment tool to evaluate learners’ process skills. The evaluations were then categorised and analysed. Figure 1 shows photographs of the classroom with learners working while conducting their scientific investigations.

Figure 1 Photographs of the learners in progress conducting a scientific investigation

4.2.2.1 Category 1 – Make accurate observations and measurements.

The learners read the case study aloud as groups. After reading, they planned the way they were going to carry out the investigation. Most used the questions to guide them in their thoughts, but some of the groups tried to find answers to the questions. These groups were reminded that the task was to conduct a scientific investigation, not simply to answer the questions. The class was given permission to use the guidelines from the manual and also to use the same ideas they had formed during the instructional sessions. When they were permitted to do so, they proceeded with their tasks and worked smoothly. All the learners used the same structure provided in the manual but added some inputs, like the hypothesis given in the questions and the background from the summary of their discussions in the instructional sessions. Appendix A.2 shows the case study, the questions given to help them in their discussions, and the tools used when they conducted the investigation. They identified the significant role of each tool they were going to use.

The groups distributed the tasks to their team members. They decided who must write down their thoughts and observations. When observing, they identified the different colours, shapes, length and thickness of the candles. However, none of the learners identified the position of the wick before and after they burned the candles or whether the wick was the same length or thickness. When the candles were burning none of them also mentioned the size of the flame, the texture of the candles, or how hot the candles, the flame and the wax were.

A maximum of two learners per group were given the task of taking measurements. They used the string and the ruler to measure the length and the thickness of the candles. There was a big debate in this stage, especially when they were measuring the thickness of the candles. Some learners said they should measure the circumference and some the diameter of the candles. They used the string to do the measuring and marked on the string the point where the measurement ended. They then put the marked string on the ruler to check the measurement. Some groups used the ruler only to measure the thickness of the candles. Other groups measured accurately, starting from zero to the mark of the string, while others started from the end or tip of the ruler to the mark on the string.

Some learners lit the candles, allowed them to burn for five minutes, and then blew them out. They then measured the length of the candles. They used the same method as when they had measured the thickness of the candles. Other learners started from zero on their stop watch and ended in five minutes, again measuring the length. Still others started from zero, stopped at five minutes to measure the length, and then proceeded for a further five minutes before taking the next measurement. Each time the learners took the measurements, they recorded the values with the units. All the groups recorded the thickness and the length in centimetres. None of them converted the centimetres to millimetres. In the same way, all the learners recorded time in minutes instead of using the S.I. units of time which are seconds. They also recorded these units in symbols, for example, cm for centimetre and min for minute.

4.2.2.2 Category 2 – Identifies fair test

Designing a fair test is one of the most important aspects to consider when carrying out a scientific investigation. This was emphasised in the discussions and explanations during the instructional sessions, when the learners were taught about scientific investigations. The same statement was also made in the questions from the case study, which learners used to help them discuss their investigation. These questions challenged them to identify all the variables that could impact on their investigations. The two questions were Questions 3 & 4, and were phrased as follows: "What variable would remain the same and what variables will change in your investigation?" Below Question 6 (the last question) was a note in bold referring learners to these two questions:

Note: Question 3 & 4; only the variables under investigation can change, all the others must be the same.

When the learners were reading the case study, almost everyone in each group had a question about the note. They discussed it but from their responses there was a sense that they were not clear about this point. The point was explained to the whole class, since it was clearly a concern for everybody. They were told that way they examined or tested any variable in science should be exactly the same way in which they treated the other variables, and that they must consider all the factors that could affect their results. To accommodate everybody, the explanation was made in both the languages (English and Xhosa) that the learners used in their school. After the explanation, they continued with their work in their groups.

While the learners were working in groups, they established that the wind which was blowing through the door and windows affected their experiment. A learner from one group asked to close the door and windows and had to ask permission from the class. The learners said,“Close the door but not all the windows, the strong wind is coming from that side of the door.” The learners could not see that they were supposed to cut the candles to the same length. Two candles were the same length, but a third candle was shorter than the other two. None of the groups cut the candles and none mentioned whether the lengths of the wicks rising from the wax of the candles were the same or not. Many of the learners lit the candles and started experimenting without considering these important points. They also lit the candles one by one, not at the same time.

Fixing these variables would have meant that the learners would have been able to control them so that they stayed constant. If they had identified the variables and ensured that they were all fixed, their experiments would have been valid. However, they did identify that there was a difference between independent and dependent variables. When they were drawing the graphs, their discussions showed that they were not sure why they needed to write certain variables on the X axis and others on the Y axis. Not all the learners identified that the length of the candles should be recorded in the Y axis, which was the dependent variable, and the time on the X axis, which was the independent variable. Some did not understand this relationship and were assisted by learners from other groups to see the difference between the two variables. Even with this help, their levels of understanding differed significantly, and some learners could still not plot the graphs. As indicated above, the note in the case study was written in bold so that the learners could see the importance of identifying these variables.

4.2.2.3 Category 3 – Collects the data

Data are fundamental to scientific investigation and by the time learners reach high school, they should be well prepared to collect and interpret data (Sadler, 2007: 113). This important statement was made in the case study that learners used. It was included as Question 6 in the questions that could help them to discuss their investigation: “How will you collect and record your data?” The same point was also made in the rubric for an investigation (assessment tool), in level 4 of the assessment criteria. By this stage, learners should be able to identify and collect data, or as it is described in level 4: `all the trends to collect data are recognized insightfully’. These trends permit the learners to plan the best way to record their results once they have collected them. They can table the results, draw graphs, explain in paragraphs or describe the results and draw diagrams that show in proportion how big something is when compared to something else.

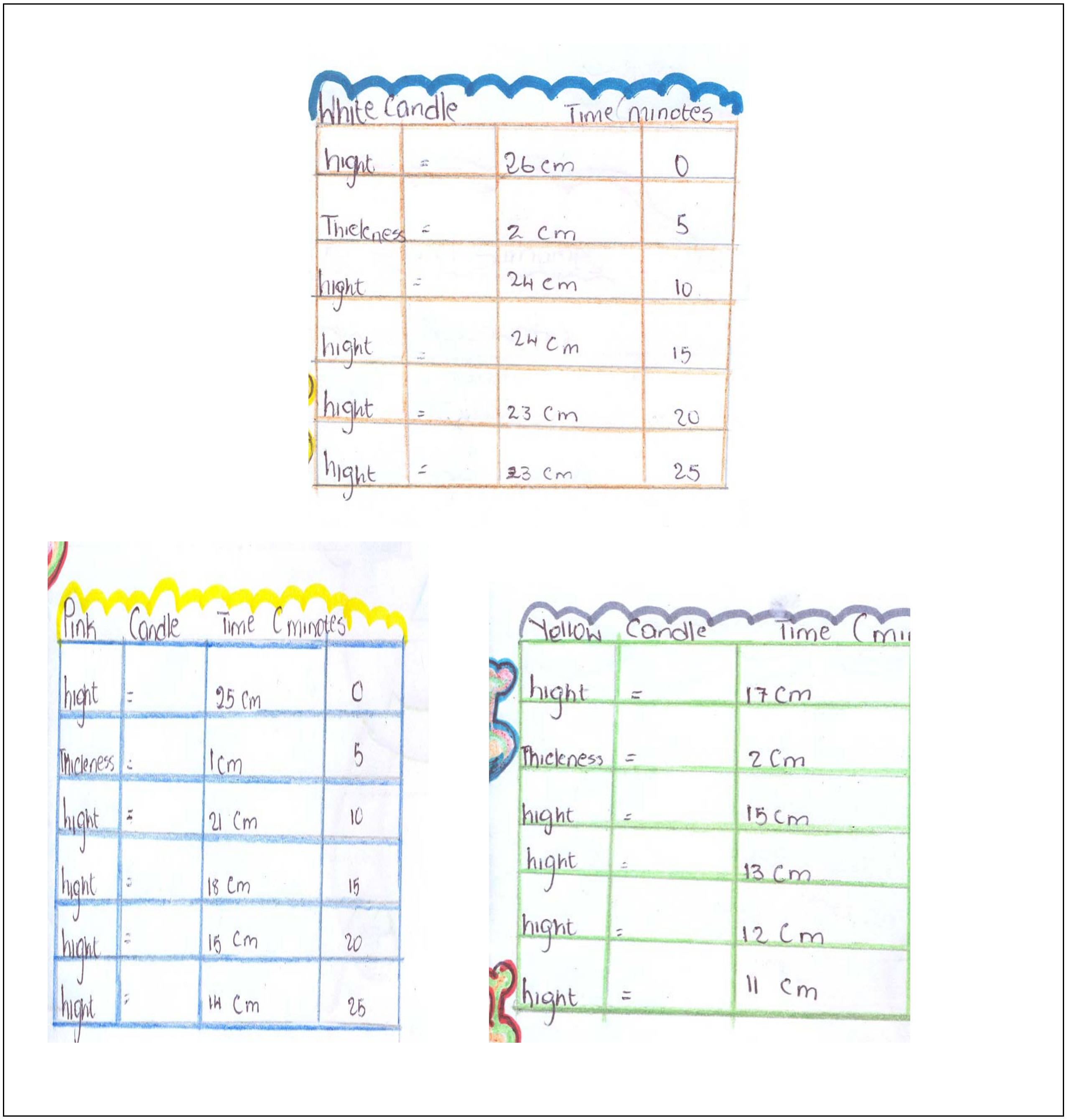
Responding to the facts mentioned above, all the learners were able to identify the characteristics of good tables used to record data. They knew that a table was a grid of columns and rows. In their tables the rows ran horizontally across the page and the columns ran vertically down the page. Some tables had headings, but the headings were not always relevant to the interpretation of the information in the table, and some tables had no headings at all. Some learners wrote one or two words instead of a sentence to describe the table. For example, to describe the table with the yellow candle, they wrote ‘Yellow or Yellow candle’. The headings were also written above the table. They understood that in each column there had to be a heading. Some groups wrote the headings in the columns with units of measurements but some did not. The groups that did not wrote the units with the values in the columns. Examples of the headings that learners wrote were `thickness’, `height’ (instead of `length’), and `the time’.

Equally important, the lines showing the columns and rows were neatly drawn using rulers. The learners realized that in a table the rows and columns listed the results for the two variables of the investigation, that is, the independent and the dependent variables. One group did not understand what they should write in their table. Figures 2.1 and 2.2 show examples of the presentations of the learners’ tables.

Result →

Red		Yellow		White	
Height	time (minutes)	Height	time (minutes)	Height	time (minutes)
24,8 cm	0	15,5 cm	0	25 cm	0
22,2 cm	5	14,7 cm	5	24 cm	5
21,1 cm	10	14 cm	10	23,8 cm	10
20 cm	15	13,8 cm	15	23,5 cm	15
19 cm	20	13 cm	20	22,8 cm	20
17,5 cm	25	12,4 cm	25	22 cm	25

Figure 2.1 Examples of the learners' tables



White Candle			Time (minotes
hight	=	26 cm	0
Thickenes	=	2 cm	5
hight	=	24 cm	10
hight	=	24 Cm	15
hight	=	23 Cm	20
hight	=	23 Cm	25

Pink	Candle	Time	(minotes)
hight	=	25 Cm	0
Thickeness	=	1cm	5
hight	=	21 Cm	10
hight	=	18 Cm	15
hight	=	15 Cm	20
hight	=	14 Cm	25

Yellow	Candle	Time (mi
hight	=	17 Cm
Thickeness	=	2 Cm
hight	=	15 Cm
hight	=	13 Cm
hight	=	12 Cm
hight	=	11 Cm

Figure 2.2 Examples of the learners' tables

Graphs are a very good way of recording and communicating information. To test this statement, forty-two learners were divided into groups of four at School X, with a total of ten groups. Seven groups avoided drawing graphs at all because they did not understand how to use them, while three groups managed to draw the graphs. The graphs from the three groups displayed a picture of a relationship between things or factors that could change, for example, the two variables. The two variables recorded by the learners were height, meaning length, and the time. One group of the three did not name the variables, but instead only wrote the values.

The three groups drew bar graphs that projected a better understanding of comparison in their scientific investigation. These bar graphs were drawn in columns to show a spread of information. There were spaces between the columns to indicate that the independent variables were not continuous. The graphs had two lines, representing the two axes. One axis was horizontal, called the X axis, and the other one was vertical, called the Y axis. The point where the X and Y axes crossed was the origin of the graph and the number zero (0) was written there to indicate that. In these two axes, the independent (X) and the dependent (Y), the variables were fully labeled except for the one group mentioned above.

The variables were given a sensible scale for each axis. The scale was kept constant but the values written were numbers from the tables and were not suitable for the scale drawn, whereas the group that did not name the variables was able to number the axes correctly. The units were given on both axes. On the X axis the groups wrote the time with units (minutes instead of seconds) and on the Y axis the height or length with units (cm). Two groups provided their graphs with incomplete headings, and some learners did not explain fully all the information plotted on their graphs, writing one word instead of a full sentence. Figures 3.1 and 3.2 show examples of the presentations of the learners’ graphs.

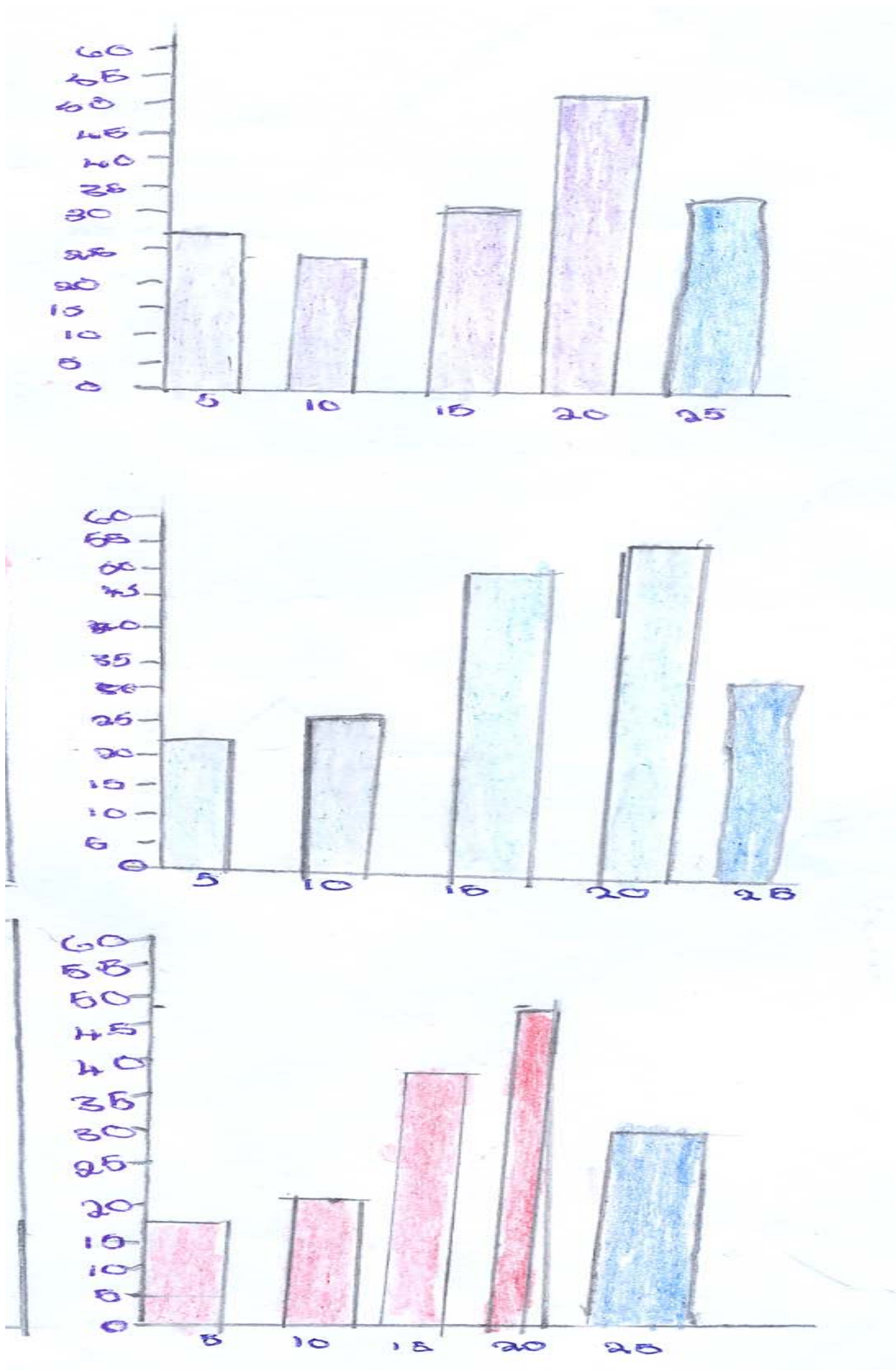


Figure 3.1 Examples of the learners' graphs

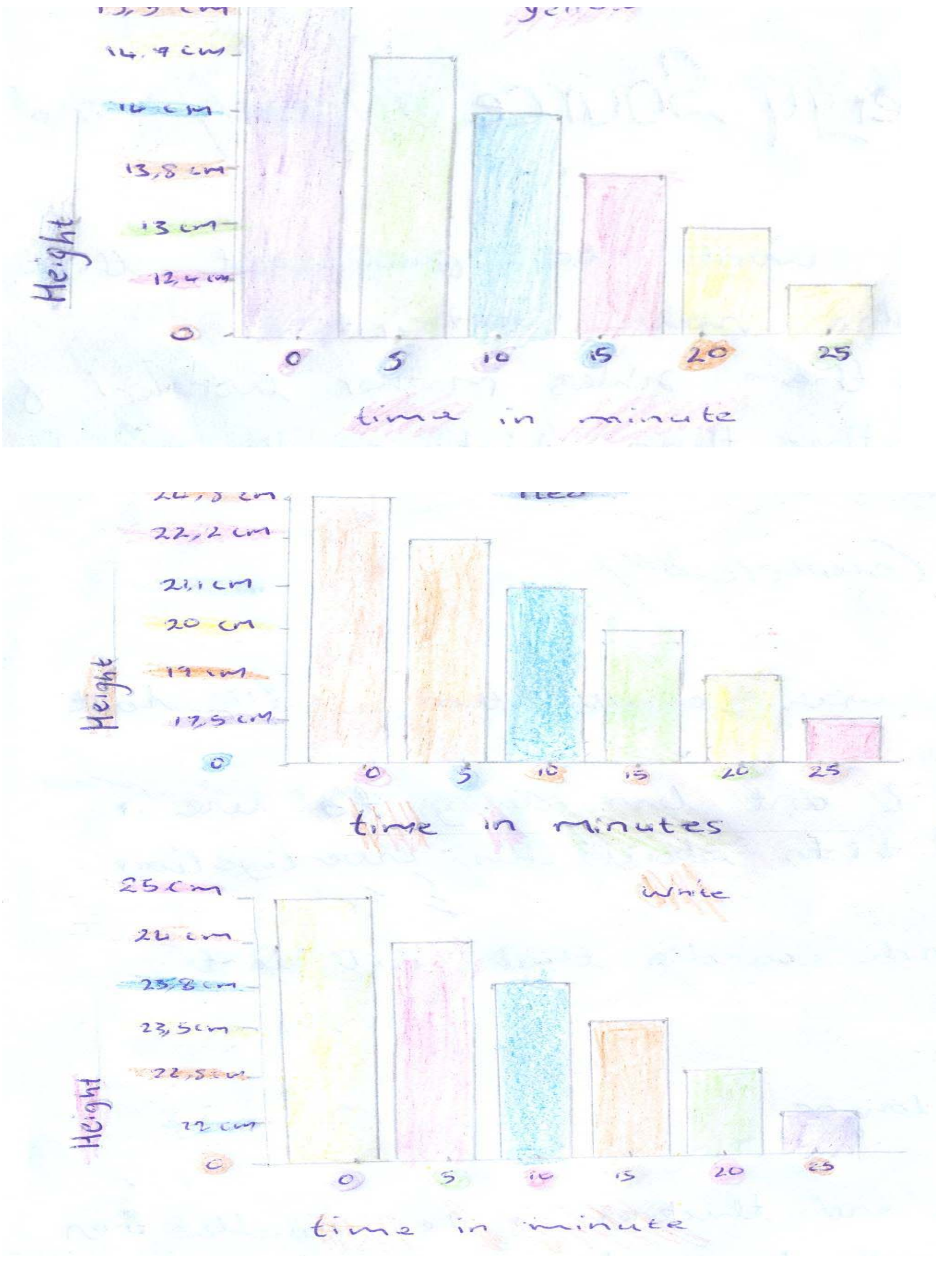


Figure 3.2 Examples of the learners' graphs

As with the two data presentation methods mentioned above, diagrams are also an important way of recording information. Two groups from the ten demonstrated how important it was to record information by drawing diagrams. These groups understood that in science diagrams are just as important as the text you write. The details drawn by one of these two groups made this especially clear. This group had an accurate outline and accurate representation of the candles. The learners in this group had observed carefully and accurately. They had considered the proportion of the candles, measuring how big one candle was compared to the others. The diagrams were drawn large enough to show all the important features clearly. Unfortunately, the diagrams had no labels and this made them meaningless. All the diagrams had incomplete headings. There was only one view on the diagrams, which was the front view, and all showed the candles while they were burning. In addition, the magnification showed how much bigger or smaller the drawing was than the real candles. Figure 4 gives examples of the learners' diagrams.

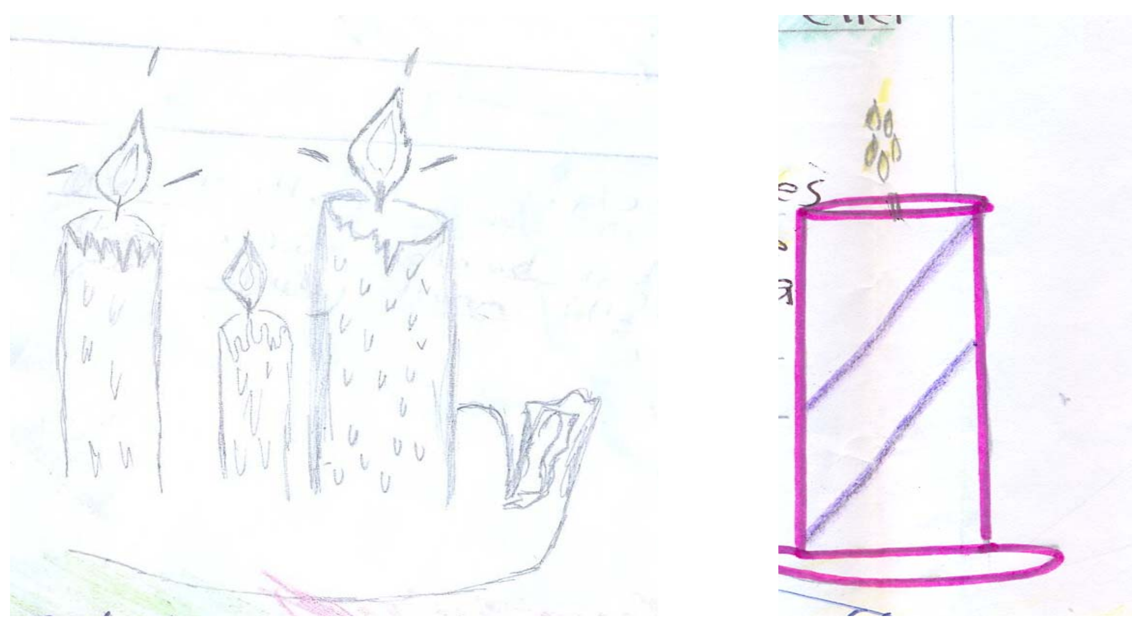


Figure 4 Examples of the learners' diagrams

4.2.2.4 Category 4 – Communicates the findings

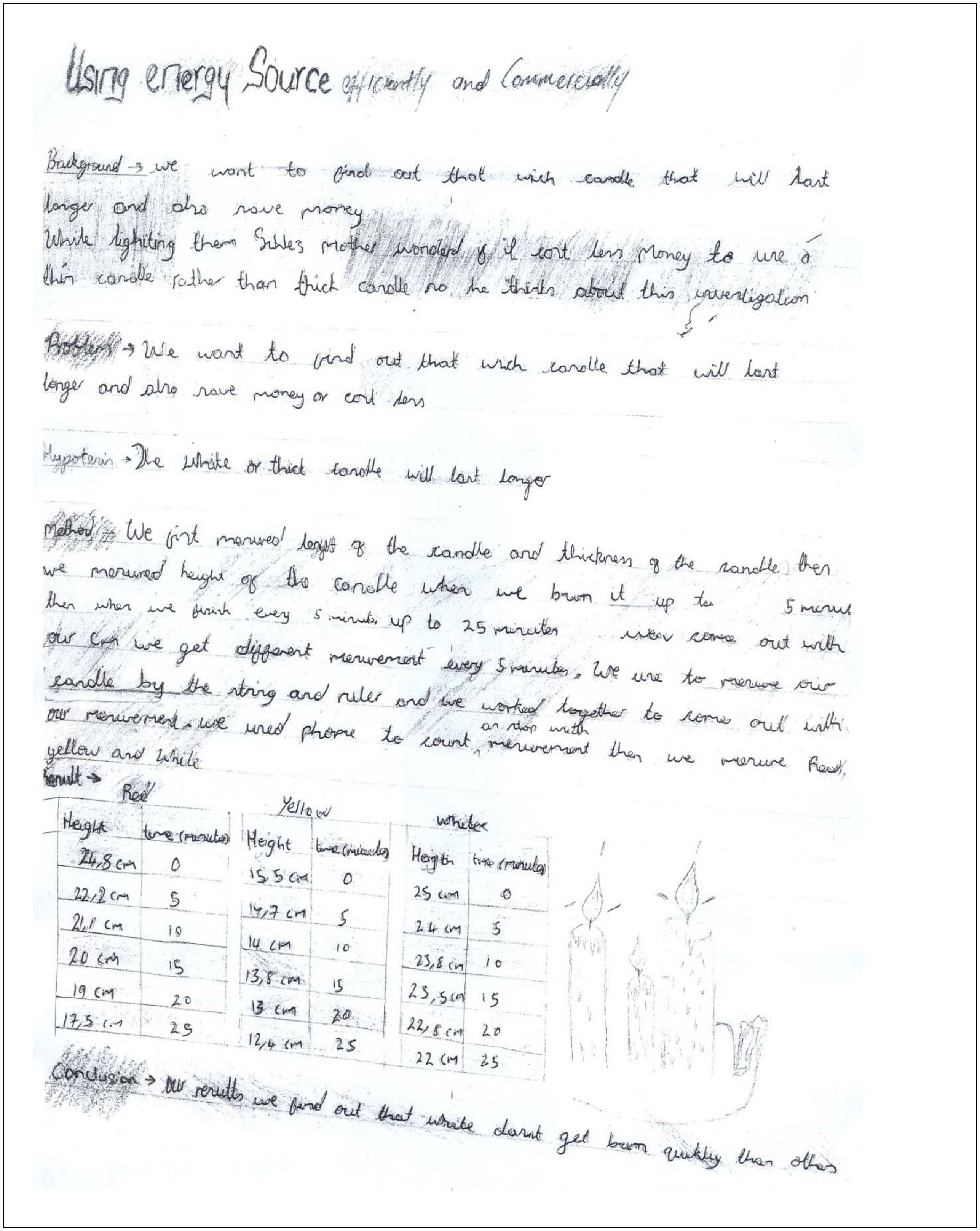
This category analysed how learners recorded and interpreted their findings. This was as important as the other three presentation methods discussed above. It was an important point at which learners could explain in detail their paragraphs or their description of the results that were collected and recorded. At the same time it was a good way of showing how well the learners could select and use scientific information in a presented format. For instance, Question 6 of the case study asks, "How will you collect and record your data?" Also in the assessment tool, level 4, it was written that a science report follows the accepted format in that is neat, well presented, has an hypothesis, an aim, apparatus, method, recording data, interpreting data and a conclusion. This was the part learners enjoyed most when they were conducting their scientific investigation.

The learners had communicated their results on an A3 sheet (poster). They understood that communicating was a way of displaying their work, and they recorded each step that was followed in their investigation. All the learners from the ten groups communicated their findings. They all provided headings of the investigation in their posters. These headings were written in bold and some were underlined. Three groups provided a full summary explanation of the information in their investigation when they wrote the headings. Two groups did not give a complete description of the investigation; instead, one group just wrote two words "Sihle's investigation" while the other group wrote only one word, "investigation". The other three did not write headings at all and one group had an irrelevant heading.

The posters were neat, written by hand for each step. The information in the steps was fairly presented. While all the learners presented this information in sub-headings, they did not provide a sufficient explanation of the steps needed. Instead, they offered only a brief description, even though two of the groups had shown an understanding of what should be written in each step. One of these two groups had satisfied the requirements expected in this category, demonstrating an ability to record, interpret, transfer and select specific information insightfully in the steps they had identified.

Most of the steps that were required in the investigation were written in sequence. The learners included the background, identified the problem that was investigated, reasoned the hypothesis, but did not include the aim of the investigation and the list of the apparatus used. They described the planning method step-by-step and how they had conducted their investigation. All the groups recorded their results in tables; however, three groups had bar graphs and two groups drew diagrams. One group came up with a well-informed conclusion, which supported their hypothesis. The other nine groups did not reach a conclusion as to what happened in their investigation or why.

On the whole, then, all the learners interpreted the information in each step, even when the information was irrelevant. At the same time they failed to interpret the tables, the graphs and the diagrams. Figure 5 shows examples of the presentations of the learners' work in which they communicated their findings.



Using energy Source efficiently and Commercially

Background → we want to find out that wich candle that will last longer and also save money
While lighting them Sihles mother wonderd if it cost less money to use a thin candle rather than thick candle so he thinks about this investigation

Problem → We want to find out that wich candle that will last longer and also save money or cost less

Hypotesis → The white or thick candle will last longer

Method → We first mesured length of the candle and thickness of the candle then we mesured height of the candle when we burn it up to 5 minut then when we finish every 5 minuts up to 25 minutes [illegible] come out with our Cm we get different mesurement every 5 minutes. We use to mesure our candle by the string and ruler and we worked together to come out with our mesurement. we used phone to count or stop wotch mesurement then we mesure Red, yellow and White

Result →

Red		Yellow		White	
Height	time (minutes)	Height	time (minutes)	Height	time (minutes)
24,8 cm	0	15.5 cm	0	25 cm	0
22,2 cm	5	14,7 cm	5	24 cm	5
21,1 cm	10	14 cm	10	23,8 cm	10
20 cm	15	13,8 cm	15	23,5 cm	15
19 cm	20	13 cm	20	22,8 cm	20
17,5 cm	25	12,4 cm	25	22 cm	25

Conclusion → our results we find out that white dont get burn quickly than others

Figure 5 Examples of the learners' findings

4.3 Interviews

Session two of the interviews was analysed in five categories. In these interviews, the learners were in groups of four; two groups were combined because some learners were absent from school on the day of this session. This reduced the total number from ten to eight groups. Summaries of the main issues raised in the interviews are presented below. Some of the learners' responses are also shown.

4.3.1 Purpose of carrying out a scientific investigation

Some learners claimed that the purpose of carrying out a scientific investigation was to enhance conceptual understanding. Others said that it was to develop their skills; they mentioned conducting a research and interviewing people. Equally a certain number of learners maintained that a scientific investigation could assist them in discovering concepts and ideas for themselves so that they could make sense of the world around them, pointing out that they used different methods to compare different things in life. Others believed that a scientific investigation could help them to make useful decisions about how to construct something and also enhanced the value of sharing information and skills.

<u>Learners' responses</u>

"Learn more about science."
"Learn to know how to get information about new and old things."
"Get information about the things around us and know how they happen."
"Research or ask questions about a topic you are given at school and to talk about something you need to do."
"Learn information and show it to other people."

4.3.2 Role of understanding process skills in scientific investigation.

The learners saw the role of understanding process skills as an important one, mentioning that they applied these skills in different activities in their daily lives. For example, the graphs they plotted showed them the relationships between different factors. Similarly the observations assisted them in noting similarities and differences and incorporating them into their own understanding. Observations also encouraged them to notice that some things happen in a particular way in the world around them. A number of learners claimed that they benefited in understanding the skill of measuring; they had to measure accurately and with care, making sure to use the correct instrument and the right measurements. Other learners saw that these skills would help them in the higher grades, as they had developed their skill in writing and in recording the steps of the investigation.

Learners' responses

"Know the differences between the same and the different things."
"Know how to draw graphs to see the difference."
"To see how things are happening."
"To know more information that we can use in the higher grades."
"Use these skills in everything we use."
"To measure the length and size of different things."

4.3.3 The advantages of understanding scientific investigation.

Some learners said it was an advantage for them to understand a scientific investigation because it helped them to think logically and also to plan their work by knowing why, when, how and what to consider when doing something. When interviewing they would need to know not only the questions they wanted to ask but also how to ask them. At the same time, a knowledge of scientific investigation would help them to select information, gain skills in reading and writing, and in listening to and following instructions.

Learners' responses

"To get information from the library to read and write it."
"Listen when you ask questions."
"When you ask people you must know what you want to ask."

4.3.4 Problems and challenges encountered when conducting scientific investigation.

Most learners identified different challenges and problems encountered when carrying out a scientific investigation. Their concerns included a lack of participation and cooperation from their group members. They said they sometimes argued and did not listen to one another. Even more importantly, the language issue was a concern of most of the learners. They often found they could not express themselves in the way they wanted. One group stated that they did not know how to fix the variables in their investigation.

Learners' responses

"Sometimes we couldn't concentrate when we were observing the candles."
"The candles were not the same size."
"Other groups were asking questions from us and that was disturbing but we helped them."
"Not everybody was working."
"Don't understand when we read sometimes."
"One person did not listen to our views."

4.3.5 Experience gained in conducting scientific investigation.

All the learners expressed excitement and joy in the activity of conducting a scientific investigation. They said the information and the presentation were new to them, and they also learnt so much about something they had taken for granted, a candle. In addition, some learners said that they had gained more information on how to carry out a scientific investigation. They also mentioned the positive competition between themselves. Lastly, they stated that they had learnt to do things for themselves.

<u>Learners' responses</u>

"Competition between the groups."
"Enjoy everything because it was new to us."
"Learn thinking without asking, Miss (facilitator)."
"It was fun."

CHAPTER FIVE

Discussion

5.1 Comparing the survey, interviews and observations

This study researched 42 Grade 9 learners' process skills and their scientific investigation ability. The main aim was to discover whether these learners could observe, measure, collect data and communicate their findings. In Chapter One, it was noted that the South African National Curriculum claims that scientific investigations and process skills serve as the framework of the science curriculum; through these, conceptual understanding and investigational skills can be developed (DoE, 2002: 13). In Chapter Two, it was also mentioned that from the age of 14 learners are capable of understanding different forms of process skills, such as drawing conclusions and constructing tests (Hassard, 2007: "no page number").

The learners in this study were between the ages of 14 and 16 years, and were given a written survey (base-line) to determine their understanding of scientific investigations. The results from this survey conflicted with the above statements. At the ages quoted, most of the learners (fifty-nine percent) could not give a direct response when asked about their understanding of scientific investigation. Only forty-one percent referred to a scientific investigation as something they wanted to know more about or to research. At the same time, forty-nine percent did understand the steps to be followed in such an investigation. However, they only understood the general procedure, and were unable to discuss the details, for example the hypothesis, the plan, or how they could record and analyse data to come up with a conclusion.

Eighty-two percent of the learners said they had conducted a scientific investigation previously in different grades and institutions, including their present school. All these learners also agreed that Natural Sciences helped them to have a better understanding of situations in everyday life. Eighty-six percent thought that a scientific investigation had some relationship to their own experiences.

The responses of these learners might simply indicate that there were gaps in the way they had conducted their previous investigations. Section 2.3 of this study noted that the investigational approach is an inquiry-based science activity, effective in enhancing scientific literacy (Llwellyn, 2004: 10), and in helping learners to reflect and to share their learning experiences (Mbano, 2004: 105).

Since the responses from these learners displayed a lack of understanding, they were given the task of undertaking a scientific investigation to extend the knowledge gained from their previous performances. The optimum mode was that they should be able to move to a deeper engagement with the task. The task was based on the assessment standards in DoE (2002: 9) which claim that by the end of Grade 9 the learner's ability to apply knowledge to simple problem-solving activities should increase. At the same time, the task was evaluated thoroughly by an assessment rubric; this concluded that the learners, combined in two groups, did not achieve the requirements for conducting a scientific investigation. The two groups scored between zero and thirty-four percent, since they failed to make accurate observations and measurements; they also could not identify a fair test, collect data or communicate their findings.

However, seven groups of learners partially achieved the requirements (thirty-five to forty-nine percent). They could observe and measure, even though inaccurately. They identified some variables, recognized simple trends while collecting data, and communicated an intelligible structure in their findings. One particular group satisfied the requirements and achieved between fifty and fifty-nine percent. They observed, measured and identified most variables, had good trends of collecting data and a coherent structure in communicating their findings.

While this group of learners satisfied the requirements of conducting a scientific investigation, a second group failed to carry out what Hinrichsen, *et al*. (1999: 10) in Section 2.2 refer to as the procedures of an investigation. These procedures are described as reading instruments accurately, taking an adequate number of trials, organizing data in logical and meaningful ways, observing in detail, transforming raw data to establish patterns or relationships between variables, and clarifying results.

After the learners had completed their observations, they were interviewed. Some learners claimed in these interviews that the purpose of conducting a scientific investigation was to develop conceptual understanding and process skills, to discover ideas for themselves so that they could make sense of the world around them, and to share information and skills. These learners could see that process skills were important in understanding their everyday life, since they could apply the skills to different situations in the world around them. Similarly, they understood the advantage of scientific investigation as a tool to help them in planning their work and thinking logically.

Even though the learners identified the challenges and problems that might hinder their progress, their key concerns were about group co-operation and language (English). At the conclusion of the project, they said that they were very excited to have conducted a scientific activity. They had gained "so much information from something as simple as a candle", as well as the process information needed to carry out a scientific investigation. They believed that the information gained would be useful in their higher grades. The way these learners responded affirmed what was mentioned in Section 2.2, that a scientific investigation enables learners to act confidently in exploiting their curiosity about natural phenomena. At the same time, their skills in performing practical work and in evaluating, for example in seeing that the candles were not all the same size, or judging whether the investigation was a fair test of an idea, were also enhanced (DoE, 2002: 9).

5.2 A complete version of the three instruments

The results derived from the observation of learners in this study showed that most were not fully able to measure, observe and collect data, or clearly to express their findings. They had difficulty in interpreting data; they attempted to interpret but the information in the steps they had identified did not correlate with the headings in those steps. Similarly, while some learners had graphs, tables and diagrams, none were successful in interpreting these findings.

Although they were less able to perform the above-mentioned skills, they could see the need to experience these types of activities. While they claimed in the interviews that conducting a scientific investigation was new to them, in the base-line activity they said they had performed one in previous grades. They had learnt to think without asking and had enjoyed the challenge. As mentioned in Chapter 2, this activity inspired them to acquire knowledge, skills and attitudes by finding things out for themselves, with the facilitator acting only as a resource (Alebiosu, 2005: 110). From the interviews it would seem that metacognition was closely related to the learners' cognitive processing levels (Mbano, 2004: 113).

Finally, as described in Section 2.4, learners should be given significantly more opportunities for involvement and initiative (Sutman, *et al.* 2008:17). This is because learning is more effective and efficient when learners have insight into their own strengths and weaknesses, and access to their own repertoires of learning (Mbano, 2004: 106).

5.3 Teaching and learning hindrances

5.3.1 Teaching

When the learners were writing the survey, most of them (eighty-two percent) said they had carried out a scientific investigation before (Table 2). They had conducted these investigations in different grades and institutions, but thirteen percent and fifty-six percent did so in Grades 8 and 9 respectively in their present school (School X). During the period of observation, an average of ninety percent did not satisfy the requirements for conducting a scientific investigation. Some claimed in the interview that they had enjoyed the activity because the information and presentation process were new to them. This meant that the learners in this school had not been exposed before to process or investigative skills activities. A possible reason for this was noted in Chapter 3, that lecturing using textbooks was the norm in teaching Natural Sciences in School X. Furthermore, the teacher of Natural Sciences at Grade 9 was not a science specialist or even a trained teacher.

The main problem was one of a heavy emphasis upon the teaching of content (Kichawen, Swain & Monk, 2004: 81). Most primary school science teachers lack sufficient knowledge of their subject, preventing them from constructing the required scientific pedagogical framework to develop the thinking and process skills learners need in science topics. They are unable to create learning environments that would encourage learners to take active control of their own learning (Ahtee & Johnston, 2006: 207 and Murphy & Beggs, 2003: 84).

Most teachers have never been engaged in learning science as inquiry (process or investigative skills) or been exposed to effective, inquiry-based institutions in their training. How, then, can they be expected to support learners' science inquiries in a manner consistent with the vision of reform (Haefner & Zembal-Saul, 2004: 1655)? If teachers are engaged in on-going professional development and use appropriate equipment, they will be able to internalize process skills. Once they understand these process skills, they will be able to apply them to any content and transform their teaching without the need for a cookbook approach, using only textbooks (Jolls & Grande, 2005: 25). Before teachers can teach subjects such as science, therefore, they should first develop a more intimate knowledge, understanding and use of process skills. Professional development and consistent practice will be necessary for them to acquire confidence and achieve success (Jolls & Grande, 2005: 26).

Lastly, the recommendation from learners in a research conducted by Murray & Reiss, (2005: 91), claims that good science teachers are crucial. Science teachers should be properly qualified to teach science and if possible have an appropriate subject specialisation within the field.

5.3.2 Language

The results from the written survey indicated that fifty-nine percent of the learners (Table 2) had no direct responses when they were asked about their understanding of scientific investigation. The main reason was the difficulty they had in expressing themselves in English. Their responses were unhelpful, making it hard for the researcher to follow their thinking. All the learners presented their findings and most included steps required in communicating a scientific investigation. Nevertheless, the information in the steps was not sufficient, with just a brief description in one or two words for the heading and subheadings. Furthermore, during interviews, learners were concerned about the use of their second language, English. They said they could not express themselves as they would like to, when communicating their findings. At the same time they did not find it easy to understand what they were reading (section 4.3.4).

In short, the use of English as the medium of instruction was problematic in this investigation since it restricted communication and reflection in the learning environment (Rambuda & Fraser, 2004: 16). The lack of a general reading and writing culture was found to further contribute to an inadequate implementation of the science process skills during their investigation (Rambuda & Fraser, 2004: 16). Nevertheless, the learners' written work did reflect many of the labours and joys that had accompanied their new discoveries (Harrell & Bailer 2004: 36).

CHAPTER SIX

Conclusion

6.1 Summing up

The results from the written survey indicated that seventy percent of the learners partially achieved the requirements for conducting a scientific investigation, twenty percent did not meet the requirements at all, and ten percent satisfied the requirements. The intention of the intervention (Appendix B) was simply to remind learners of the steps involved in doing a scientific investigation. The majority of the learners (seventy percent) could observe and measure, even though inaccurately, and could identify some variables. They recognized simple trends during data collection, but showed an incoherent structure in communicating their findings. The results revealed that most of the learners had a limited number of process skills, which restricted them in performing to their best level. Although most of them appeared to have a skeleton idea of what was expected of them in conducting a scientific investigation, problems relating to teaching styles and language skills were evident.

It was clear from the findings that the learners sampled in this study were no different from other South African learners with poorly developed language skills, both in their first language and in English, the medium of instruction (teaching and learning) at School X (Webb, Williams & Meiring, 2008: 6). While South Africa has eleven official languages, the official languages for instruction are English and Afrikaans. This study confirms the Third International Mathematics and Science Study (TIMSS, 2003) report that in countries such as South Africa, where a large proportion of learners do not speak the language of instruction at home, science achievement scores are generally lower. These scores show that there is an association between lower achievement and those learners who do not speak the language of instruction at home (Reddy, Kanjee, Diedericks & Winnaar, 2006: 89 & 90).

Since science teaching and learning are especially dependent on language proficiency (Reddy, *et al*. 2006: 89), learners need to become proficient in talking, writing and reading about science (Webb, *et al*. 2008: 5). Science teaching and learning is a process which requires the embedding of explicit language tasks during instruction (Webb, *et al*. 2008: 5). It is important to note that, while the emphasis of the science curriculum is generally on scientific literacy, the social dimension of science should also receive adequate attention (Nampota, 2008: 29). Scientific literacy is interpreted in two interacting senses, the fundamental sense in which individuals are proficient in the language of science and the derived sense in which they understand the Nature of Science (NOS) (Webb, *et al*. 2008: 5). The science curriculum includes the teaching and learning of scientific investigations and process skills, which allow learners to air their alternative conceptions and come to an authentic explanation of what they observe in developing their reasoning (Webb, *et al*. 2008: 15).

The science curriculum also utilizes science process skills instruction or engagement in scientific investigation activities to improve conceptions of the Nature of Science, or NOS (Abd-El-Khalick & Lederman, 2000: 665). NOS is defined as the total sum of the `rules of the game', leading to knowledge production and the evaluation of truth claims in the natural sciences (McComas, 2004: 25). Webb, *et al*. (2008: 6) point out that the detailed associations between claims, data, background information and rebuttals of authenticated explanations in science need a print record to document ownership of the claims. This is the process whereby learners make a claim, and provide suitable evidence to justify and defend their claim in a logical way. Hogan, (1998: 52) refers to the nature of science as an understanding of and perspective on the nature of learners' own science knowledge-building practices and the scientific knowledge they form or encounter. Knowledge about the nature of science is tied to learners' school contexts, and thus might mediate their daily learning of science in school.

Understanding the nature of science should not only help learners function in our schools and society but could also enrich their lives by making them insiders who can share in the `science adventure story' as it unfolds (Hogan, 1998: 52). Science teachers should therefore be expected to learn about NOS as part of their training in science process skills and involvement in scientific investigations. Learners should be presented with numerous hands-on, activities-centered, inquiry-oriented science experiences in order to develop a more comprehensive view of science. It is crucial to define the knowledge base deemed necessary for teaching NOS, both to pre-service students and as part of in-service teacher training (Abd-El-Khalick & Lederman, 2000: 690 & 692). There is overwhelming evidence that the quality of teacher preparation and qualification strongly influences learners' level of achievement. Among the many factors that affect learners' progress in natural sciences, the teachers' pedagogical knowledge and skills in their subject area are acknowledged to be the key factors (Laugksch, Rakumano, Manyelo & Mabye, 2005: 273).

Laugksch, *et al*. (2005: 273) make it clear that adequate skills and knowledge in natural sciences are a vital component of contemporary life and the socio-economic development of South African learners. As mentioned in the TIMSS report of 2003, over two-thirds of science learners in South Africa were taught by teachers who indicated that they had studied science in their pre-service training courses. South African science teachers could therefore be classified as qualified and knowledgeable in their subject areas. However, in relation to the TIMSS cadre of teachers, South African science teachers appear among the group having the lowest qualifications. Statistically, South African teachers attended a higher number of professional development activities than the international average for courses related to science content, science curriculum, improving critical thinking and science assessment. However, there was a relatively low percentage reporting on professional development activities relating to science pedagogy or instruction, which is surprising given that the new curriculum introduced a different way of organizing classroom activities (Reddy *et al*. 2006: 110 - 111).

In summary, the results of this study showed that most of the learners had limited abilities in conducting a scientific investigation. The main reason for this was that the use of English as the medium of instruction discouraged learners from expressing themselves in the different activities they were performing. Moreover, it was clear from their responses in the interviews that they had not been exposed to such projects before, claiming that the activities were new to them.

The implication of this study is that for learners to improve process skills in science they need to perform scientific investigation activities regularly, and to write up and defend their results so that they can learn how knowledge in science is developed. As much as there is a need for learners to perform well in their scientific investigations, there is also a need for teachers to be professionally developed in the pedagogy of science instruction. In particular, the reading or writing instructions on science content and the process or investigative skills instructions for primary school teachers who are not science majors should be clear and easy to understand.

6.2 Recommendations for future research

The time allocated for collecting the data in this study was too short to allow a thorough feedback to the teacher and learners so that the learners could rectify their mistakes. In general, therefore, it is recommended that science teachers should practice carrying out simple science investigations to expose learners in their classrooms to such investigations. At the same time, science teachers should work hand-in-hand with Mathematics and English teachers to eliminate the problems and challenges encountered in investigative or process skills activities.

Future work should concentrate on finding appropriate ways of analysing the process skills and infusing the language skills into those process skills. These might include, for example, instruction in setting up science notebooks with dividers for vocabulary, affixes and chapter content, oral reading timings, writing skills such as summarizing, concept mapping skills, and more extensive research-writing skills, as described by Carnine and Carnine, (2004).

Appendices

Appendix A.1

Written survey:

Natural Sciences

Base-line assessment

Please complete the following questionnaire.

One of the main skills that learners acquire in order to understand science is to learn how to carry out a scientific investigation.

1. What is your understanding of a scientific investigation?

   …………………………………………………………………………………

   …………………………………………………………………………………

   …………………………………………………………………………………

   …………………………………………………………………………………

2. What steps must you follow when you carry out a scientific investigation?

   …………………………………………………………………………………

   …………………………………………………………………………………

   …………………………………………………………………………………

   …………………………………………………………………………………

   ………………………………………………………………………………....

3. Have you carried out a scientific investigation before?

   …………………………………………………………………………………

Where?

……………………………………………………………………………………

What grade were you in when you carried out a scientific investigation?

…………………………………………………………………………………….

4. Natural sciences should help me better understand situations in everyday life. Why?

……………………………………………………………………………………

……………………………………………………………………………………......

....

....

5. I think to understand scientific investigation has little relation to what I experience in the everyday world. Why?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………….

Appendix A.2

Participator's observation:

INVESTIGATION

Learning Outcome 1

Theme: Energy and Change

Topic: Using energy sources efficiently and economically

Time: 3-4 Hours

Case study

In South Africa, we use a number of different sources of energy. Electricity is the main source of energy for industry and business. However, many homes use wood, paraffin and coal as their source of energy for heating, cooking and lighting. All these sources of energy, if not used carefully, have negative impacts on the environment.

The Dlamini family had very high electricity bills at home. Now they are much more careful. They switch off lights when they leave a room, and try to wear warm clothing rather than switch on the heater as soon as it gets a bit chilly. The family has replaced their incandescent light bulbs with compact fluorescent bulbs, which are five times more energy efficient than the old-fashioned ones.

While this family was sitting down for the evening meal one night, a crash was heard outside. Everything became extremely quiet as the power supply in the house shut down. All the lights, the TV and the radio switched off and everything was in darkness. After a moment of absolutely silence, everybody started scrambling for the candles. Sihle, a Grade 9 learner at School X Primary, finds thin and thick candles. While lighting them, his mother wonders if it costs less money to use thin rather than thick candles. He thinks about this and decides to carry out an investigation.

In your classroom, divide yourselves into groups of four and decide how you will carry out Sihle's investigation.

These are the questions that can help you to discuss your investigation:

1. What problem are you trying to solve?
2. What would your hypothesis be?
3. What variable would remain the same?
4. Which variables will change?
5. What finally did you do to come up with your results? (method)
6. How will you collect and record your data?

   Note: Questions 3 & 4: only the variables under investigation can change, all the others must be the same.

Now perform your investigation.

- Start with the hypothesis, and
- Then state the aim, the apparatus, method of collecting data and recording your data, and the conclusion.

You will need:

- Different sizes of candles
- Watch
- Ruler
- Matches
- String

Appendix A.3

Assessment tool

Rubric for an investigation

Assessment Criteria	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Make accurate observations and measurements	Cannot observe and measure	Can observe and measure incorrectly	Can observe and measure correctly	Can observe and measure accurately
Identifies whether it is a fair test	Cannot identify the variables	Can identify some variables	Can identify most variables	Identifies all the variables, the controlled, the independent and the dependent
Collects the data	Trends are not correctly or accurately recognized.	Simple trends recognized in collecting data	Good trends in collecting data	All the trends to collect data are recognized insightfully
Communicates the findings	Not coherent or structured	Sketchy and not acceptable structure	Coherently structured, accepted format but misses certain steps	Science report follows the accepted format, very neat, well presented, has hypothesis, aim, apparatus, method, recording, interpretation and conclusion

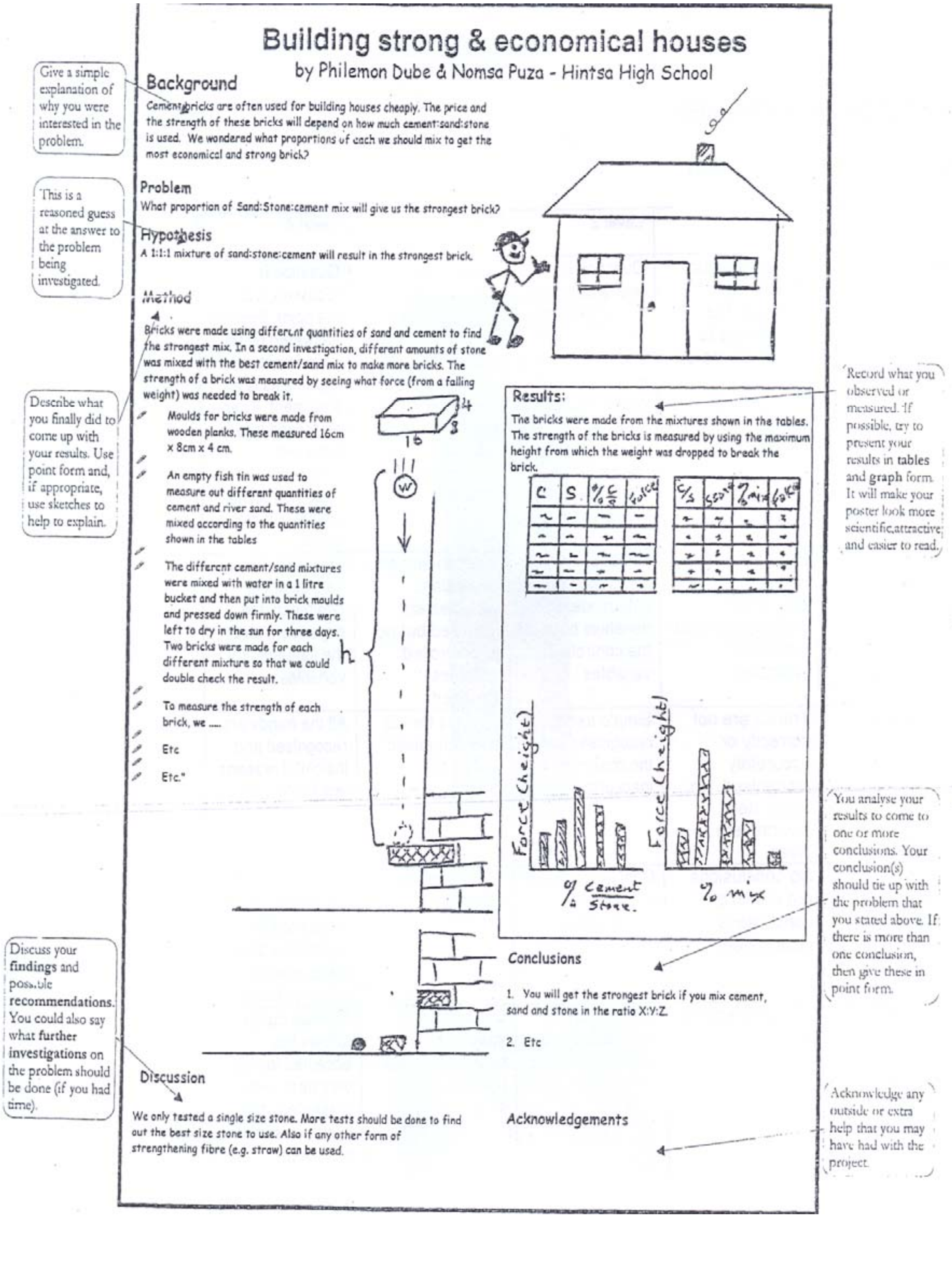
Appendix A.4

Interview questions:

1. What is the purpose of carrying out a scientific investigation?
2. What is the role of understanding process skills in scientific investigations?
3. What are the advantages of understanding scientific investigation?
4. What problems and challenges did you encounter when you were conducting your scientific investigation?
5. What do you think about this experience?

Appendix B

Support material – manual



Building strong & economical houses

by Philemon Dube & Nomsa Puza - Hintsa High School

Give a simple explanation of why you were interested in the problem.

Background

Cement bricks are often used for building houses cheaply. The price and the strength of these bricks will depend on how much cement:sand:stone is used. We wondered what proportions of each we should mix to get the most economical and strong brick?

This is a reasoned guess at the answer to the problem being investigated.

Problem

What proportion of Sand:Stone:cement mix will give us the strongest brick?

Hypothesis

A 1:1:1 mixture of sand:stone:cement will result in the strongest brick.

Describe what you finally did to come up with your results. Use point form and, if appropriate, use sketches to help to explain.

Method

Bricks were made using different quantities of sand and cement to find the strongest mix. In a second investigation, different amounts of stone was mixed with the best cement/sand mix to make more bricks. The strength of a brick was measured by seeing what force (from a falling weight) was needed to break it.

- Moulds for bricks were made from wooden planks. These measured 16cm x 8cm x 4 cm.
- An empty fish tin was used to measure out different quantities of cement and river sand. These were mixed according to the quantities shown in the tables
- The different cement/sand mixtures were mixed with water in a 1 litre bucket and then put into brick moulds and pressed down firmly. These were left to dry in the sun for three days. Two bricks were made for each different mixture so that we could double check the result.
- To measure the strength of each brick, we ....
- Etc
- Etc."

Record what you observed or measured. If possible, try to present your results in tables and graph form. It will make your poster look more scientific,attractive and easier to read.

Results:

The bricks were made from the mixtures shown in the tables. The strength of the bricks is measured by using the maximum height from which the weight was dropped to break the brick.

You analyse your results to come to one or more conclusions. Your conclusion(s) should tie up with the problem that you stated above. If there is more than one conclusion, then give these in point form.

Conclusions

1. You will get the strongest brick if you mix cement, sand and stone in the ratio X:Y:Z.
2. Etc

Discuss your findings and possible recommendations. You could also say what further investigations on the problem should be done (if you had time).

Discussion

We only tested a single size stone. More tests should be done to find out the best size stone to use. Also if any other form of strengthening fibre (e.g. straw) can be used.

Acknowledge any outside or extra help that you may have had with the project.

Acknowledgements

Appendix C

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

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Verwysing
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ISalathiso

Ms Christiana Conana
13 Newport Road
BERNADINO HEIGHTS
7570

Dear Ms C. Conana

RESEARCH PROPOSAL: AN EVALUATION OF GRADE 9 LEARNER'S PROCESS SKILLS AND THEIR SPECIFIC INVESTIGATION ABILITY.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **1st September 2008 to 26th September 2008**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.

Signed: Ronald S. Cornelissen
for: **HEAD: EDUCATION**
DATE: 29th August 2008

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