

**PHYSICAL SCIENCE ACTIVITIES AND SKILLS DEVELOPMENT
IN THE SCHOOL CURRICULUM OF NAMIBIA**

By

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I declare that **PHYSICAL SCIENCE ACTIVITIES AND SKILLS DEVELOPMENT IN THE SCHOOL CURRICULUM OF NAMIBIA** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE
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DATE

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ABSTRACT

Grade 12 learners in one Namibian secondary school participated in a study of science process skills implied in their International General Certificate of Secondary Education (IGCSE) physical science syllabus. The study aimed at finding out learners' ability to identify science process skills in their physical science syllabus, criteria used to identify skills and whether any relationship existed between learners' achievement in performing skills and learners' ability in identifying the skills. Four physical science syllabus topics were taught. Learners performed and identified science process skills in learning and assessment tasks. A One Group Pretest-Posttest research design was used in a combined qualitative and quantitative research method. Data revealed that learners identified science process skills. Science processes performed during learning experiences were used as criteria to confirm presence of the skills. Learners' achievement increased in performing and identifying science process skills after intervention activities. There seemed no relationship between learners' achievement in performing and learners' ability in identifying science process skills.

KEY TERMS

Physical science, science process skills, constructivist learning theory, cooperative learning, verbalisation, Namibia Senior Secondary Certificate, International General Certificate of Secondary Education, identify/perform process skills, Achievement in process skills, quantitative and qualitative research methods.

LIST OF ABBREVIATIONS AND ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
CIA	Central Intelligence Agency
HIV	Human Immunodeficiency Virus
IGCSE	International General Certificate of Secondary Education
INSTANT	IN-Service Training and Assistance for Namibian Teachers
NSSC	Namibia Senior Secondary Certificate
SAPA	Science-A Process Approach
SMICT	Science, Mathematics and ICT
SPS	Science Process Skill
ROSE	Reform of Secondary Education

DEDICATION

This study is dedicated to my late father and late mother for their God given vision that a girl-child can also achieve academically and professionally. This has formed a basis for my motivation in education.

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CHAPTER 1

SITUATING THE PROBLEM AND THE STUDY

1.1 INTRODUCTION

Prior to independence in 1990, Namibia shared a common secondary school curriculum with South Africa. Since independence Namibia has been offering the International General Certificate of Secondary Education (IGCSE) curriculum in senior secondary schools. In the year 2005 the curriculum was localised and arrangements for assessment and certification were completed (Office of the President 2004:62). Physical Science was one of the subjects in the Natural Science field of study. Other subjects were English Second Language, Silozi First language, Natural Economy, Mathematics and Biology. The localised Physical Science syllabus is similar to the IGCSE in structure (topics, general objectives, specific objectives and assessment objectives).

In the previous political dispensation Namibia experienced inequalities in education between the white, coloured and black populations. One such inequality was that learners from the coloured and black population would usually not pursue the study of science and mathematics after junior secondary education. Teachers were poorly trained which led to poor learner achievement. The situation for mathematics and science education was so desperate that an intervention was imperative (Ottevanger et al 2005:37). The development and implementation of the In-Service Training and Assistance for Namibia Teachers (INSTANT) Project was to address these inequalities. Project activities included designing and implementing a new science and mathematics curriculum in secondary education. Management of teacher

training emphasised learner-centred instructional approaches (Clegg 2003:22). Such instructional approaches are recommended for the effective teaching of science to develop scientific skills and illustrate concepts (Ottevanger et al 2003: 16). The government of Namibia is committed to implement the effective teaching of science. This stance is reflected in Vision 2030 – a vision Namibia has for the state of science teaching by 2030. The government of Namibia plans to have a rapid increase in enrolment in the field of Natural Science at both the University of Namibia and the Polytechnic of Namibia. The expectation is that demand for professionals in the natural sciences will increase tenfold by the year 2030 (Office of the President 2004:64). The successful development of science process skills in learners will make a contribution towards better understanding, achievement and interest in science. Such a situation will possibly lead to aspired increased enrolment for science in tertiary institutions, thus contributing to the success of Vision 2030. The focus of this thesis is the study of skills development in Physical Science activities and such a study was conducted with grade 12 learners at an urban senior secondary school in the Caprivi region of Namibia. The term “learner” is used interchangeable with the term “student”.

1.2 STATING SCIENCE PROCESS SKILLS IN SCIENCE CURRICULA

The stating of science process skills is done in two ways. One way is to list them. The other is to describe them as part of science syllabuses.

1.2.1 SCIENCE PROCESS SKILLS – IN LISTS

Two ways of listing science process skills are described. One way is as listed in the *Revised National Curriculum Statements for Grades R-9(Schools) for Natural Sciences* (Department of Education 2002:13, 14). The skills are:

“observing and comparing...measuring...recording information...sorting and classifying...interpreting information...predicting...hypothesizing ...raising questions about a situation...planning science investigations ...conducting investigations...communicating science information”.

The second way categorises the skills hierarchically into Basic Science Process Skills and Integrated Science Process Skills. Basic skills are: observing, classifying, measuring, inferring, predicting and communicating. The Integrated Science Process Skills include: identifying, defining and controlling variables, collecting and transforming data, constructing tables and graphs, describing relationships between variables, interpreting data, analysing investigations, manipulating materials, designing investigations, experimenting, constructing hypotheses and drawing conclusions and generalising (Germann & Aram 1996, in Beaumont-Walters & Soyibo 2001:133, 134; Rambuda & Fraser 2004:14, 16). Screen (1986) in Arena (1996:1) showed that the basic science process skills “provide a foundation for the acquisition of integrated science process skills”. This demonstrates the hierarchical interrelationship of the skills.

1.2.2 SCIENCE PROCESS SKILLS AS PART OF SCIENCE

SYLLABUS

One of the first science programmes focusing on the skills was the Science –A Process Approach (SAPA) for the advancement of science in America

between 1963 and 1974. The science instruction in elementary and high schools focused on the teaching of science process skills (Bredderman (1983) in Beaumont-Walters & Soyibo (2001:133). In Jamaican Reform of Secondary Education (ROSE) Project, science process skills to be acquired by learners were listed in teachers' guides and not specified in the syllabus (Beaumont-Walters & Soyibo 2001:134). Science process skills are prominent in some curricula. There are two examples in South African curricula. One is the *Revised National Curriculum Statement for Grades R-9 (Schools) for Natural Sciences* (Department of Education 2002: 6, 17). A second example is the *National Curriculum Statement for grades 10-12 (General) for Physical Sciences* (Department of Education 2003:13). In both examples science process skills are reflected in outcomes stated in Natural and Physical Science syllabuses. Details of the skills are described in assessment standards. In contrast to the case of South Africa, Namibia (where the study is conducted) skills are not clear in the IGCSE syllabus content but stated in assessment objectives.

In the Namibian school where this study was conducted, the senior secondary phase (grades 11-12) offered IGCSE curriculum. The localised curriculum was to be offered in three fields of study. The fields are Home Economics, Commerce and Natural Science for the attainment of the Namibia Senior Secondary Certificate (NSSC). Physical Science is one of the subjects in the Natural Science field of study together with Biology, Development Studies, English Second Language, Mathematics and Silozi First Language. The structure and organisation of the Physical Science syllabus is similar to IGCSE Physical Science syllabus. For the purpose of this study the focus is on the IGCSE Physical Science syllabus. One example of a topic in the chemistry

part of the syllabus is the topic “chemical reaction” with one of the subtopics called “speed of reaction”. The content of this subtopic is given below:

5.3 speed of reaction

- describe the effects of concentration, particle size, catalysts (including enzymes) and temperature on the speeds of reactions.
- state that organic compounds that catalyze reactions are called enzymes-describe the application of the above factors to the danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. mines)

(University of Cambridge International Examinations 2004: 6)

The content knowledge, given above guides teachers in teaching the topic to prepare learners for writing IGCSE Physical Science assessment items (examinations). Specific in the content are action verbs such as *describe* and *state* which indicate to teachers the processes that form the focus of the learning experiences during instruction.

Below are assessment objectives that describe the IGCSE Physical Science syllabus content which learners should have knowledge of and understand (University of Cambridge International Examinations 2004: 2):

1. scientific phenomena, facts, definitions, concepts and theories,
2. scientific vocabulary, terminology and conventions (including symbols, quantities and units),
3. scientific instruments and apparatus, including techniques of operation and aspects of safety,
4. scientific quantities and their determination,
5. scientific and technological applications with their social, economic and environmental implications.

The objectives state specific scientific phenomena, vocabulary, instruments and apparatus, quantities and technological applications requested for in

examinations. The objectives augment teachers' guidance in preparing and teaching Physical Science lessons.

Other IGCSE Physical Science assessment objectives for handling information and problem solving are set out in the Physical Science syllabus by University of Cambridge International Examinations (2004: 2):

1. locate, select, organize and present information from a variety of resources.
2. translate information from one form to another,
3. manipulate numerical and other data,
4. use information to identify patterns, report trends and draw inferences,
5. present reasoned explanations for phenomena, patterns and relationships,
6. make predictions and hypotheses,
7. solve problems.

These objectives describe skills not stated in the syllabus content because questions testing the skills utilise information that is unfamiliar to learners (University of Cambridge International Examinations 2004:2).

The last assessment objectives for experimental skills and investigations (University of Cambridge International Examinations 2004:2) are

1. use techniques, apparatus and materials (including the following of a sequence of instructions where appropriate),
2. make and record observations, measurements and estimates,
3. interpret and evaluate experimental observations and data,
4. plan investigations and /or evaluate methods and suggest possible improvements (including the selection of techniques, apparatus and materials).

The objectives describe skills that learners use when conducting experiments and investigations.

To achieve the three sets of assessment objectives, learners need to develop understanding and application of science process skills. An assessment of learners' achievement was done by writing three examination papers at the end of a two-year course of study. In the IGCSE Physical Science syllabus the paper 6, Alternative to Practical examination paper testing experimental skills and investigations contributed 20 per cent towards a learner's final assessment grade (University of Cambridge International Examinations 2004:2). For NSSC Physical Science syllabus, the Practical Skills and Abilities examination paper on the same skills contributed 30 per cent towards the learner's final assessment grade (Ministry of Education 2005:40, 41). The increase in the percentage for the skills in the examination serves as evidence of the importance the government of Namibia places on experimental skills and investigations in the teaching of science at school.

The implementation of changes in how experimental skills and investigations are viewed must be contextualised in the results of ongoing Science, Mathematics and ICT (SMICT). The study investigates the cost implications of conducting practical work when teaching science. Results indicated that practical work in some schools in Namibia proved problematic because the schools lacked basic science equipment. This situation obliged the government of Namibia to assess learners' skills by administering IGCSE paper 6, called the Alternative to Practical. It was a written examination that did not include conducting experiments. Learners in most secondary schools wrote this paper. The examination paper required learners to have had done

practical work to internalise experimental skills and investigations during their course of study. The SMICT study results showed that questions in this paper were “not answered well by the learners who had done little practical work” during their school science instruction (Ottevanger et al 2003:8, 9).

The likely implication of the study is that Physical Science teachers should follow a deliberate strategy to teach science process skills as part of learning outcomes of any Physical Science syllabus. This should apply even if the syllabus does not state science process skills in its content. For Physical Science teachers in Namibia some science process skills are indicated in new Physical Science syllabuses. The new Junior Secondary Phase Physical Science syllabus for grades 8 to10 has a topic called scientific processes. A section for grade 10 shows science process skills of “Estimating, measuring, observing and handling information...Recording and presenting results...Evaluating and reasoned explanation of results” (Ministry of Education 2006:5). The new Namibian Senior Secondary Certificate Physical Science syllabus has a subtopic called scientific skills. The section states science process skills of “recording data...Drawing graphs and tables” (Ministry of Education 2005:4).

1.3 MOTIVATION FOR THE STUDY

Three factors contributed towards the motivation for this study. First, there seemed no published research studies on the teaching of science process skills in Namibia, especially in the Caprivi region. Second, in line with a study by Germann et al (1996:97), science process skills form the fundamental basis for doing science. My experiences as a teacher of IGCSE Physical Science at the school hosting this study in Namibia supported the view expressed by Ottevanger et al (2003:9), namely that most learners who wrote IGCSE

Physical Science examinations without having practised science process skills during instruction seemed unable to perform and apply process skills in examination items. Support is given for the view by Monk and Dillon (1993:17, 18) that instruction in science should include practical/performance work involving process skills for learners to construct new knowledge. Third, the NSSC Physical Science syllabus was similar to IGCSE Physical Science syllabus in its content and organization. This implied that results of this study would apply equally to the NSSC Physical Science syllabus. The research study results were expected to provide other dimensions for further research in the teaching of science process skills on how learners internalise skills during the learning process of Physical Science in similar settings to this study.

1.4 PURPOSE OF THE STUDY

This study investigates three characteristics of secondary school learners in Namibia during the teaching of the IGCSE Physical Science syllabus topics using science process skills. Three research questions were formulated in this regard. Firstly, could learners identify science process skills implied in the syllabus? Secondly, could learners describe the criteria used in identifying the science process skills during the process of performing the skills in assessment items for the syllabus? Thirdly, was there any relationship between learners' abilities to perform and identify science process skills in assessment items of the syllabus?

1.5 DEFINITIONS OF TERMS

Terms defined in this section arise from the research questions. The definitions indicate how the terms are used in the study.

1.5.1 IDENTIFY

This refers to a situation in which a learner executes a given skill and uses the experience to recognise the skill and describe it. The emphasis is on performing the skill prior to naming it.

1.5.2 CRITERIA

This is a set of tangible occurrences that confirm the presence of a particular skill. For example a learner's action of reading temperature from a thermometer and writing it down confirms the presence of the skill of measuring.

1.5.3 ABILITY

This refers to what extent learners use their initiative and knowledge to confirm the presence of a skill (identify) and provide a numerical or descriptive response to questions that require application of the skill.

1.5.4 ASSESSMENT ITEMS

These are questions asked on knowledge and application of the IGCSE Physical Science syllabus content (specific to science process skills). The questions are adaptations of the past IGCSE examinations.

1.5.5 ACHIEVEMENT

This is how high a learner scores marks allocated to identifying and executing a skill to provide a correct response to a given assessment item or part thereof.

1.6 LIMITATION OF THE STUDY

This study is limited to the ability of learners to perform and identify science process skills in their IGCSE Physical Science syllabus in one Senior Secondary School in Namibia. This was a case study based on this school only. The application of findings of this study is therefore limited to the school that hosted the study and schools in a similar situation. Since this study might be the first of its kind in the country, its application should be done cautiously until the study is replicated and its dimensions extended to various instructional settings.

1.7 SUMMARY

The political independence of Namibia in 1990 marked a curriculum change for schools. The South African secondary school curriculum was replaced by the University of Cambridge International General Certificate of Secondary Education (IGCSE) curriculum. Localisation of the curriculum was to be completed in 2005. The In-Service Training and Assistance for Namibian Teachers (INSTANT) Project was implemented to address previous inequalities in science instruction. Continued improvement in science instruction is envisaged in Vision 2030, a policy framework for long-term national development.

The IGCSE Physical Science syllabus for Namibia was described by topic content and assessment objectives for knowledge with understanding, handling information and problem solving and experimental skills and investigations.

Motivation for the study arose from three observations: the first one being the poor learner achievement in science due to poor teacher preparation.

Secondly, it was recognised that science process skills are fundamental in doing science. Thirdly, knowledge gained from the researcher's experience as a Physical Science teacher in the school that hosted the study. This was coupled with commitment by the Namibian government towards the effective teaching of science subjects. The purpose of the study was to establish whether learners could identify and perform science process skills implied in their IGCSE Physical Science syllabus, and to see if there was any relationship between learners' abilities to perform and identify science process skills. The result of the study is to be applied cautiously until the study is replicated.

1.8 SUMMARY OF CHAPTERS

1.8.1 CHAPTER 1: SITUATING THE PROBLEM AND THE STUDY

The historical background of Namibia is described. Science process skills are stated in science syllabuses and the need for teaching them in Namibia is explained.

1.8.2 CHAPTER 2: LITERATURE REVIEW

Science process skills are defined followed by a discussion of constructivist learning theories and the description of the scopes of the skills. Functions and development of the skills conclude the chapter.

1.8.3 CHAPTER 3: RESEARCH ACTIVITIES

Research questions are listed. A research design and activities are described. Qualitative and quantitative methodologies are described in how they complement each other in the study. Details of sampling, instrumentation and data collection are provided.

1.8.4 CHAPTER 4: ANALYSIS AND DISCUSSION OF RESULTS

Qualitative data (scopes of science process skills) and quantitative data (scores from identification and performance of skills) are presented. The discussion of the results shows responses to research questions. The chapter concludes with key findings of the research study which form the basis for the formulation of recommendations in chapter 5.

1.8.5 CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The chapter discusses the conclusion of the research findings to present a direction for making formulated recommendations. The significance of the research findings is highlighted and this points to the need for conducting more research studies.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The review of relevant literature contextualises the research study in two ways. Firstly, by discussing learning theories underlying instructional strategies used in science instruction. Secondly, it contextualises the research by describing the scope and development of science process skills in science curricula. The term “process skill” is used interchangeably with the term “science process skill”.

2.2 THEORIES OF LEARNING UNDERPINNING INSTRUCTION IN SCIENCE

Theories of learning play an important role in guiding teachers in how best to teach science. The teaching and learning of science process skills cannot be done without applying theories of learning in instructional settings. Therefore, before discussing scopes and the development of science process skills, it is logical to examine learning theories that have an impact on the development of the skills.

A major shift has occurred in theories of learning from the objectivist view to the constructivist view which has impacted the teaching and learning of science. Hendry (1996:24) describes the objectivist view as “certain people can aspire to become privileged holders of valid representations of real entity knowledge, or authorities compared with less experienced students”. This view led to a teaching and learning practice in which teachers (authorities)

hold the scientific content knowledge that is transmitted to learners.

Consequently, common teaching practices are “characterised by telling and showing, or the giving of objective knowledge...During lessons, students...typically are expected to listen and/or watch” (Hendry 1996:25).

This makes learners passive in lessons. Hand and Vance (1995:37) claim that

in the past, teachers of science and mathematics generally promoted ‘correct’ procedures for problem solving, and the need for students to acquire essential knowledge. As a result many teachers perceived learning to primarily involve a transfer of knowledge that was ‘passed onto’ students. Students’ knowledge was not the focus of teaching and learning within the classroom

The constructivist view, on the other hand, holds that “learners construct knowledge for themselves...each learner individually (and socially) constructs meaning...as he or she learns” (Hein 1996:1). This view places the focus on the learner’s construction of knowledge.

The constructivist theory of learning is the one that underpins teaching and learning strategies recommended for teaching science at school. These strategies are used during research tasks for the learners in this study.

Therefore, elaboration of this learning theory is needed to show the basis for learners’ activities of the research tasks.

Brewer (1971:1, 2) indicates that three authorities can be associated with the constructivist learning theory. The first is Jean Piaget, who believed that

the development of human intellect proceeds through adaptation and organization. Adaptation is a process of assimilation and accommodation, where external events are assimilated into existing understanding, but unfamiliar events, which don’t fit with existing

knowledge, are accommodated into the mind, thereby changing its organization

The second is Lev Vygotsky, whose view was that

... the child gradually internalizes external and social activities, including communication, with more competent others...that learning environments should involve guided interactions that permit children to reflect on inconsistency and to change their conceptions through communication.

The third is John Dewey who believed that

... knowledge and ideas emerge only from a situation in which learners have to draw out experiences that have meaning and importance to them...that human thought is practical problem-solving, which proceeds by testing rival hypotheses. These problem-solving experiences occur in a social context, such as a classroom, where students join together in manipulating materials and observing outcomes.

Despite the fact that Piaget, Vygotsky and Dewey were all proponents of the constructivist theory of learning, they had different instructional strategies for classroom settings. For Piaget an individual learner must interact with instructional materials to construct knowledge. This implies that in a classroom situation, a learner should work alone (Brewer 1971:2). Vygotsky stressed the role of language for communication with peers or teachers during the time learners interact with (manipulate) materials, with the goal to construct knowledge (Howe 1996:37, 46). This calls for the use of group work during practicals and discussions during lessons. Dewey wanted to use real problems in learning situations (Brewer 1971: 1, 2).

It seems the three implementation strategies of constructivism described above have influenced the teaching of science collectively. The result is that a

learning situation should have the following five characteristics. Firstly, it should view science as a method which involves the construction of knowledge about nature (Hand & Vance 1995:38). Secondly, the construction of knowledge is done socially. The social construction of knowledge implies the use of group work. The group can be small or the whole class can be involved to provide learners with what Solomon (1987) in Hand and Vance (1995:41) calls “a public forum for both testing their knowledge and extending and expanding it” through practical work and discussions. Brewer (1971: 2, 3, 4) describes the last three characteristics. One of them (third characteristic) is the role of the teacher as facilitator. This requires teachers themselves to be experienced students in order to guide learners in learner-centred activities. The fourth characteristic is learners’ prior knowledge; their existing knowledge about the content matter. The construction of knowledge occurs when new information fits into prior knowledge. Teachers must establish learners’ prior knowledge of the content matter before proceeding with further teaching. The fifth characteristic is the use of real-life problems for learners to participate in problem solving and critical thinking skills.

The discussion of learning theories has highlighted a shift from the objectivist to the constructivist views of teaching and learning science, namely that learning does not occur by transferring knowledge but by constructing it. For this to happen, science instruction should involve learners in group work. Teachers should be facilitators, learners’ prior knowledge should be utilised in lessons and learners should be engaged in solving problems. The constructivist theory of learning has implications for the development of science process skills.

2.3 DEFINITION OF SCIENCE PROCESS SKILLS

Science process skills are defined in a variety of ways. The following are examples. In the *Revised National Curriculum Statement for Grades R-9 (Schools) in Natural Sciences* (Ministry of Education 2002: 13), “the term ‘process skills’ refers to learner’s cognitive activity of creating meaning and structure from new information and experiences ... are applicable across all the three Learning Outcomes”. Padilla (1990:1) calls these skills a “set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists”. Process skills are described as a “sequence of events which are engaged by researchers while taking part in a scientific research investigation,” and are “generally related to proficiency in the ‘doing’ aspects of science associated with cognitive and investigative skills” (Arena 1996:34).

Common elements in the definitions are that science process skills are cognitive abilities used in investigations in science for constructing scientific knowledge and are transferable to other curriculum disciplines.

2.4 DESCRIPTION OF SCOPE OF SCIENCE PROCESS SKILLS

In this section, scopes of science process skills are described under the categories of Basic Science Process Skills and Integrated Science Process Skills. The scopes refer to actions which would constitute the skill being described. The description is based on multiple views of the skills by Germann and Aram (1996) in Beaumont-Walters (2001:133, 134); Brotherton and Preece (1996:66); Germann et al (1996:83); Georgia Department of

Education (1999-2003); Valentino (2000:2) and Department of Education (2002:13, 14) including the researcher's personal experiences.

2.4.1 BASIC SCIENCE PROCESS SKILLS

These skills “provide the intellectual groundwork in scientific enquiry, such as the ability to order and describe natural objects and events” (Beaumont-Walters & Soyibo 2001:133). Therefore scopes of the skills below should reflect the mentioned characteristics.

Observing

This involves a process whereby the senses of touch, smell, sight, hearing and taste are used to describe the properties, differences and similarities of objects and events. The description is either in words (e.g. brown crystalline substance) or in numerical format (e.g. 4 cm long).

Measuring

This involves the use of standard instruments (e.g. laboratory clocks, rulers) to find or make estimations to describe length, mass or time for objects or events. Measurements are recorded in units, for example 5 meters, 10 seconds and 5 grams.

Classifying

This involves organising objects, events or sequences according to characteristics, similarities or differences. Results of classifying can be in tables such as a periodic table, lists of strong/weak acids and charts of substances grouped into elements, compounds and mixtures.

Communicating

Communication involves the use of the spoken or written word to present and explain experiences and ideas to others. The written work can be in the form of text, pictures, graphs, charts, maps, drawings, diagrams, posters, concept maps, drama, demonstrations, tables and any other information presentations.

Inferring

This involves using observations and previous experiences to make conclusions about some phenomena. This may include cause and effect relationship. Results of inferring are statements showing relationships between or among variables in an investigation.

Predicting

This means that observations, measurements and inferences are used to form an idea of expected results. Predictions are statements /explanations showing the relationships between variables in the event. The statements are made orally or in written form.

Using number relationships

Numbers and their relationships are used to make decisions. One example is when a force is exerted on an object to move it some distance. Work done by the object is calculated by multiplying force applied on the object by the distance the object moves in the direction of the force.

2.4.2 INTEGRATED SCIENCE PROCESS SKILLS

These skills are hierarchically and cognitively higher than the basic skills, they “are the terminal skills for solving problems or doing science

experiments” (Beaumont-Walters & Soyibo 2001:134). The ability to carry out these skills can be ascribed to higher level reasoning. The skills described below should display these characteristics:

Formulating hypotheses

This refers to stating the expected outcomes of experiments based on observations. Statements are predictions of relationships between variables in experiments which can be tested. One example is that increasing temperature or/and increasing concentration of hydrochloric acid increases the rate of reaction of hydrochloric acid and magnesium metal. This idea can be tested by conducting experiments.

Identifying and controlling variables

Identifying and changing/ keeping constant conditions that can change the outcomes of an experiment. The conditions are called variables. For example, in an experiment to compare weights of objects, the size of force of gravity on the objects is a variable that must be controlled because it can influence the results of the experiment.

Generalising

This is the process of identifying data that support conclusions and help to draw general conclusions. Generalisations can be statements of hypotheses that include interpolating / extrapolating between or beyond data points respectively.

Collecting data

This entails the gathering of qualitative (observations) data and quantitative (measurements) data from experiments and recording the data systematically in tables, lists or in other ways.

Interpreting data

To interpret data means to organise the data collected from experiments into tables, drawings and graphs and to identify trends or patterns in the sets of data to establish generalisations or to formulate hypotheses.

Operational definition

This means describing how to measure a variable or explaining the meaning of an object or an event. It includes how an observation or a measurement can be made. Descriptions or meanings must be given in language the learners understand.

Experimenting

This entails a set of operations. Firstly, appropriate questions (stating hypotheses) to be investigated in experiments are formulated. Secondly, experiments are planned (identifying variables in the experiment). Thirdly, the procedures are carried out. This includes controlling variables alongside the use of apparatus. Lastly the collected data (observations or measurements) are recorded and interpreted to draw conclusions based on the experiment.

These scopes of science process skills form a frame of reference for assessing the identification of science process skills by learners in the research tasks.

The described scopes are not exhaustive because of the diversity of

descriptions of the same science process skills. The description of scopes of the same skills in the Georgia Department of Education (1999-2003) provides a suitable example. Process skills called *integrated* in this study are referred to there as *higher level process skills*. Specific departures include the inclusion of manipulation, drawing conclusions and formulating models. Despite using different names, constituents of high level process skills are a combination of constituents of integrated science process skills of generalising, interpreting data and formulating hypotheses in this study.

2.5 FUNCTIONS OF SCIENCE PROCESS SKILLS IN SCIENCE CURRICULA

This section elaborates on the idea that science process skills are cognitive abilities. The focus is on how these cognitive abilities are employed in the instruction and application of science. Two situations are considered.

The first situation involves that science process skills contribute to the “understanding of science methodology – the basis element of science literacy” (Colvill & Pattie 2003: 21). According to Ostund (1992) in Mabie and Baker (1996:2), these skills are building blocks for the development of critical thinking necessary for solving problems and for supporting the process of inquiry in science. In this way science process skills can be considered to be “fundamentals of ‘doing’ science” (Germann et al 1996: 97). From a teaching and learning point of view, science process skills are “building blocks” for constructing science activities and a “means by which the learner engages with the world and gains intellectual control of it through formation of concepts” (Department of Education 2002: 13). Consequently, in South

Africa science process skills are “one of the outcomes that must be acquired by learners when studying science” (Rapudi 2004: 52).

In the second situation science process skills are linked to science and technology. Rillero (1998: 3, 4) indicates that science process skills and science content complement each other. The link is applicable also to content in studies for any profession with processes in studies for that profession. One such profession is engineering. Engineers should have the scientific knowledge of the properties of stress and strain in materials to use such materials in designing structures. Harlen (1999: 131) further explains that science process skills do not only prepare scientists for learning science “but in terms of the whole population, who need ‘scientific literacy’ in order to live in a world where science impinges on most aspects of personal, social and global life”. The area where today’s society lacks knowledge is in the area of technology. Inal (2003: 3, 5) explains, that “the development of a modern society requires scientifically and technologically literate people”. He further explains that “doing science not only develops specific skills but also enhances the learning of scientific and technological principles, laws and concepts”. This demonstrates that science process skills play a role in developing scientific and technological knowledge needed by scientists and technologists. Other professions that show a link with science process skills are in the field of the social sciences. In a study of the perceptions of Geography teachers in the Free State province of South Africa, results indicated that learners were exposed, mostly, to basic science process skills. The conclusion of the study was that science process skills should be “operational outcomes whose mastery should be regarded as foundational to

all learners' understanding of Geography as social or physical science” (Rambuda & Fraser 2004:16, 17).

Literature shows that science process skills build scientific literacy in people, by directing the doing of science. The skills form learning outcomes of science syllabi to prepare scientists and technologists and are applied in the teaching of other subjects in school curricula.

2.6 DEVELOPING SCIENCE PROCESS SKILLS

The development of science process skills is discussed by considering two methods. One method is to teach the skills and the other method is to assess them despite the overlap of teaching and assessing during the instruction of science.

2.6.1 DEVELOPING SKILLS BY TEACHING THEM

Developing science process skills by teaching them can be done in several ways. One way is to consider science process skills as building blocks of scientific literacy. In line with this view Colvill and Pattie (2002, 2003) describe how basic science process skills of classifying, measuring and using space and time relationships and integrated science process skills of interpreting data, controlling variables, formulating hypotheses and experimenting can be taught. Specific examples are given. One such example is the skill of interpreting data. Learning experiences should include “interpretations from maps (weather, contour), graphs, tables, news bulletins, photographs and lists of symbols” (Colvill & Pattie 2003:21). Specific sample activities are using pictures and symbols in electricity and measuring by using a diagram of a tree or any other diagrams. The monitoring and assessment of

the skills can be done on each skill by observing how learners perform tasks during teaching sessions over a period of time. This must also be included. One skill that can be developed through teaching is the interpretation of graphs. A study on interpretation practices used by university students and professional scientists when examining graphs was done in Canada. The study was part of a larger study on “the development of competency in scientific representation practices from elementary school to professional practice” (Bowen et al 1999:1023). For a period of thirteen weeks students were given lecture notes by using an overhead projector with minimum conversation between the students and the lecturers. Furthermore, a fifty-minute seminar was conducted every week. Crucial in the seminars was the collaborative work that included questions and answers and storytelling sessions between the teaching assistants and the students. Assessment of students’ achievement was done by examinations written during teaching time. The study acknowledges the importance of students working together to construct knowledge. This teaching strategy is effective not only for university students but also for school learners, for example those in grade 8. The recommendation is that learning environments on interpreting graphs should have students interact with peers and teachers while working on data, especially their own collected raw data (Bowen et al 1999:1040, 1041).

Science process skills can be taught as part of implementing a science curriculum. Basic and integrated science process skills were taught as part of implementing a science curriculum in schools for learners in grades 7 and 8 for a period of 20 weeks. Basic science process skills included observing, measuring, inferring, classifying, predicting, using number relationship, using space/time relationships, recording and displaying data. Integrated science

process skills were interpreting data, defining operationally, controlling variables and formulating hypotheses. Class teachers utilised directions on how to teach a course using practical work, encouraging thinking approach and enacting process skills in investigations. The teachers were also provided with plans for all lessons and homework, inclusive of work to be done during the holidays. To assess learners' achievement two tests were administered. Results showed that teaching was effective in developing the science process skills in the learners (Brotherton & Preece 1996:66, 72).

Teaching strategies are also important. Exploratory research was done with grades 5 and 6 Hispanic and African-American learners in Los Angeles. One group of learners participated in an on-going vegetable garden project which lasted ten weeks. The other group of learners participated in three short in-class projects also lasting ten weeks. The short projects involved baking bread, rearing chicks and germinating seeds. The aim of all these projects was to assess the impact of "experiential agricultural instructional strategies" (Mabie & Baker 1996:2) upon science process skills development. A hands-on assessment of skills was done. Although with limitations to the application of the results, it showed that the experiential teaching enhanced acquisition of science process skills in agriculture (Mabie & Baker 1996:2, 3, 5).

Other teaching strategies, using the Jigsaw and the Group Investigation cooperative methods, were used to teach the basic science process skills of observation and controlling variables and the integrated science process skills of graphing and experimenting in South Africa. Results showed that learners who were exposed to the Group Investigation cooperative method achieved the skills of graphing and experiment. Skills of observation and controlling

variables gave mixed results. Therefore the Group Investigation cooperative method was recommended for developing science process skills (Rapudi 2004:33, 35). Supporting the cooperative teaching strategy is a computer simulation used for teaching science process skills to college students enrolled in science education methods, majoring in Biology and Elementary Education. The cooperative learning strategy benefited both groups in learning the science process skills. Students majoring in Elementary Education felt empowered to teach the same skills to their learners. Those majoring in Biology were able to transfer knowledge of skills in similar investigations (Lee et al 2002: 40). Cooperative learning is supported further by a review of the literature. Small groups comprising four to six learners participated in collaborative learning. Results showed higher achievement in students' understanding of evidence (Bennett et al 2004:11). It seems that cooperative and collaborative instructional strategies do not only benefit students in tertiary education, but also learners in elementary and secondary education.

Specific to collaborative and cooperative learning in small group work is the social construction of knowledge aided by verbalisation. According to Wood, Yackel et al (1991) and Yackel, Cobb and Wood (1992) in Hendry (1996:31), teaching strategies that utilise verbalisation engage learners in processes that include

- (a) persisting to solve problems,(b) explaining solutions to others,
- (c) listening to and trying to make sense of others' explanations, (d) indicating agreement and disagreement, (e) questioning others about their solutions, (f) justifying explanations to others and (g) attempting to reach agreement or consensus in situations where a conflict between interpretations or explanations has become apparent.

Furthermore, in science classrooms such constructivist teaching strategies involve learners in group work that provide them with an opportunity to test their knowledge and elaborate on it. The work can be practical and performed in groups accompanied by discussions.

Support for verbalisation in collaborative and cooperative classroom interactions is evident from computer supported collaborative learning. In a conceptual framework for computer supported collaborative learning,

verbalising ideas in collaborative interactions enables learners to be aware, not only of their own discrepancies in understanding (as with the 'self explanation' effect), but also their partner's discrepancies in understanding. This compels them to express their own knowledge, requiring them to articulate their understanding, which may uncover further discrepancies of their own (Price et al 2003).

In a class where discussions between the teacher and the learners were part of a teaching programme, allowing learners to verbalise and reflect on their thinking made them aware of their active role in their own learning experiences (Maor & Phillips 1996:3).

2.6.2 DEVELOPING SKILLS BY ASSESSING THEM

Sometimes science process skills are explored by focusing on assessing the skills. An example is the assessment of learners in grades 7, 8 and 9 to establish hierarchical characteristics of skills and their link to Piagetian development levels. Results supported the two levels in the hierarchy of basic and integrated science process skills. The results also showed a parallel link of basic to integrated skills as is the case with concrete to formal levels in the Piagetian development levels (Brotherton & Preece 1995:6, 10).

Another example is the study done in Missouri involving students in grade 7. The purpose of the study was to develop a research framework that could be used to assess students' responses to the skill of designing an experiment. This led to proposing a working model for interpreting future studies. The result of the assessment of this skill was a research framework and an assertion that science process skills are "fundamentals of doing science" (Germann et al 1996:82, 97). Another study with similar focus was done on skills involving recording data, analysing data, drawing conclusions and providing evidence. Results showed that to perform the skills, students needed "metacognitive skills that include the differentiation and coordination of theory and practice". Furthermore a skill of communication was considered important, especially for writing reports (Germann & Aram 1996:795).

A different scenario is the assessment of skills as part of the implementation of a curriculum. In the Reform of Secondary Education Science Curriculum of Jamaica, integrated science process skills of recording data, interpreting data, generalising, identifying variables and formulating hypotheses were assessed. Findings revealed that the performance of learners in these skills was unsatisfactory because the learners were not taught all of the skills and because teacher-centred teaching methods instead of learner-centred methods were used. It is recommended that in order for learners to acquire science process skills, they need to be taught the skills formally. Immediate feedback should be given on learners' tasks. Finally, assessment should be done using both written and performance/practical tasks (Beaumont-Walters & Soyibo 2001:134, 142).

A literature review indicates that science process skills can be taught formally in several ways through performance/practical tasks. One way is to teach them as an isolated programme or part of implementing a science curriculum in which learner-centred instructional strategies should be used. These strategies are cooperative and collaborative work and involve small group discussions in which learners engage in verbalising their thoughts. The strategies are recommended by the constructivist theory of learning. The other way is by assessing the skills. Assessment can be either a separate programme or a component of a teaching programme. Assessment reveals the levels of learners' achievement on the skills and diagnosis of problems in teaching and learning the skills.

2.7 SUMMARY

In this chapter the shift in learning theories from the objectivist to the constructivist approach in science instruction is acknowledged. This is important because learners should construct scientific knowledge. This forms the philosophical underpinning of instruction strategies of collaborative and cooperative learning experiences. Small group discussions are recommended for developing science process skills.

Science process skills are categorised into basic (observing, measuring, classifying, communicating, inferring, predicting and using number relationship) and integrated (formulating hypotheses, identifying and controlling variables, generalizing, collecting data, interpreting data, operational definition and experimenting). The skills are defined as cognitive abilities used in investigations for constructing scientific knowledge and are transferable to other curriculum disciplines. They form learning outcomes of

science syllabi to build scientific literacy by directing the learning of science and are applied in teaching other subjects. Science process skills can be developed by formal teaching using cooperative and collaborative learning strategies in performance/practical and written tasks of subjects in any curriculum.

CHAPTER 3

RESEARCH ACTIVITIES

3.1 INTRODUCTION

This chapter states the research questions, and discusses the research design for the study. A qualitative supplemented by a quantitative research methodology is discussed. Sampling, instrumentation and data collection are described.

3.2 RESEARCH QUESTIONS

The following research questions are pertinent to this study:

- (1) What science process skills do learners identify for IGCSE Physical Science syllabus taught in Namibia senior secondary schools?

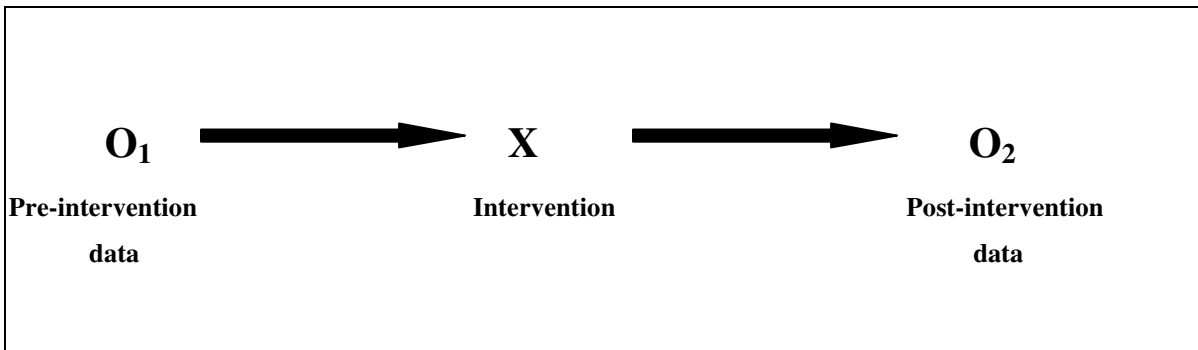
- (2) What criteria do learners use to identify science process skills in learning experiences and in assessment activities for the syllabus?

- (3) Is there any relationship between learners' ability to identify science process skills and their performance of the skills?

3.3 RESEARCH DESIGN

A One Group Pretest-Posttest design was used for the research activities. A graphic representation of this design is shown below.

Figure 3.1 Graphic representation of research design



In the design, O_1 and O_2 refer to two sets of data for each. One set is the qualitative learners' description of scopes of science process skills. The other set is the quantitative numerical scores from learners' performance and the identification of science process skills when doing tasks. Letter X represents learning experiences employed during lessons for teaching the four IGCSE Physical Science topics using science process skills.

Further discussion of the design requires defining population, sample and subject as they relate to any research study. According to Fraenkel and Wallen (1990:67, 214), a sample is a group on which data are obtained. A population is a bigger group to which results of a research can be applied. By implication the term "subject" is indicated within the context of referring to subject characteristics. A subject is an individual in a sample.

Fraenkel and Wallen (1990:214-220, 225) discuss the advantages and disadvantages of the research design described above. One advantage of the design is that it enables a researcher to establish any change in the characteristics of individuals who form the focus of the study. This is because pre-test observations form baseline data, which means that pre-test data are

used as a reference point when compared to post-test observation to describe a change as an increment or a decrease. In this research pre-intervention scores of science process skills, marks on performance and identification of the skills enabled the researcher to determine whether learners were able to identify science process skills or not. The design has disadvantages which are called threats to internal validity because they influence the results of the study. These are negative effects of maturation of subjects, mortality of subjects, location of the study, testing, history and instrument decay coupled with the characteristics of data collectors.

In this study some threats were controlled. Mortality rate was minimized probably because learners did not want to lose out since they were to write external IGCSE examinations. Maturation of learners was minimized by conducting the research over a period of four months instead of longer periods of time. Mental maturation could, however, not be controlled to zero because of instruction in other subjects. Threats due to instrument decay and characteristics of data collectors were minimised by having the researcher mark learners' worksheets and collect data alone. Threats due to testing were controlled by using different sets of questions for individual learner's worksheets in the pre-test and post-test phases. But each set of questions tested the same science process skills. However, since these learners were to write examinations later in the year their use of past examination papers could have had a slight influence on some of them. Threats due to location did not arise because the researcher was already familiar with learners and they were already using the science laboratory for teaching and learning Physical Science.

3.4 RESEARCH METHOD

The study used a qualitative method within which a quantitative method was required. Justification for using both methodologies requires a description of the fundamental philosophies underpinning these methods.

3.4.1 PHILOSOPHIES UNDERPINNING RESEARCH METHODS

Quantitative research methodology is based on a philosophy or paradigm of realism or positivism giving a realist/positivist/objectivist world view that “what research does is to uncover an existing reality. ‘The truth is out there’ and it is the job of the researcher to use objective research methods to uncover the truth”(Sukamolson n.d.). Paradigm assumptions for quantitative research are that: (1) the researcher is independent of the research, and (2) the research uses a deductive approach which “begins with known theory and tests it, usually by attempting to provide evidence for or against a pre-specified hypothesis” (Casebeer & Verhoef 1997: 3). The assumptions befit the description that quantitative research “is the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect” (Sukamolson n.d.). In addition examples and advantages of quantitative research are stated. The examples are survey research, experimental research, correlational research and causal-comparative research methods. The advantage is the extensiveness of how the results from a sample can be applied to a population.

Qualitative research methodology has a philosophical underlying of subjectivism also called interpretism giving rise to a subjectivist/interpretist world view that “there are multiple realities, not single realities of phenomena, and that these realities can differ across time and place” (Neill 2006: 1).

Paradigm assumptions of qualitative research are that: (1) a researcher is involved in the research, (2) the research uses an inductive approach that “begins by making observations, usually in order to develop a new theory” (Casebeer & Verhoef 1997: 3) and (3) the researcher gathers qualitative research data in the form of words, pictures or objects, presented verbally or in written form. This leads to a “design that emerges as the study unfolds” (Neill 2007: 1). This means that qualitative research deals with collection, examination and interpretation of non-numerical observations to discovering underlying meanings and patterns of relationships (Casebeer & Verhoef 1997: 2). Examples include case studies, ethnographic studies and phenomenological studies. Neill (2006:3) explains that the main advantage or strength of qualitative research is the depth of observations to reveal details of the phenomena or patterns that emerge in a situation.

3.4.2 COMPLEMENTARY USE OF QUALITATIVE AND QUANTITATIVE RESEARCH METHODS

Although the philosophical underpinnings of quantitative and qualitative research are fundamentally different, the two research methodologies can be mixed in the same research study. There are three supporting arguments for this proposal. Firstly, support emanates from post-positivists who believe that researchers should try to establish their reality in the best way possible, by realising that their own subjectivity can influence that reality (Sukamolson n.d.). Secondly, support comes from the nature of information required. For example, an awareness campaign for informing students about the effects of drinking alcohol requires surveys to establish the number of students that drink. Using a survey indicates a quantitative research method. The campaign used focus groups to find out why students drink or do not drink. This data is

non-numerical which indicates a qualitative research method (Smith 2008: 2). In studies of chronic diseases such as HIV/AIDS, the need to do a survey involving people with HIV/AIDS is done by assessing changes in their quality of life followed by conducting experimental intervention of two treatment regimes (Casebeer & Verhoef 1997: 8). Thirdly, support comes from Sukamolson (n.d.). The use of qualitative and quantitative research methods in the same research study is called the mixed approach method. This approach is suitable in research studies in which one aspect of the research focuses on an in-depth observation to assess the quality of the variables under observation. The other aspect focuses on the breadth to quantify the variable under study with an aim of generalising the results to a population in the study. The mixed method approach is flexible because the qualitative and quantitative components can be equal or one can dominate the other. The component sizes depend on what a researcher aims to establish in the study. In this research articulating science process skills seemed to precede the identification of the skills. This is probably because the writing of scopes is tantamount to defining the meaning of the skills. The researcher's hunch is that without grasping the meaning of science process skills learners will experience problems in conceptualising the theoretical constituents of each skill. Therefore the presence of scopes proved the learners' readiness to engage in identifying the skills. Scopes of skills formed non-numerical data. In addition to collecting data by having learners write scopes of skills, the researcher kept personal records of how learners interacted with each other as they debated ideas in groups during intervention sessions. The researcher occasionally engaged some learners in conversations. The researcher's notes were also non-numerical. The notes and conversations were not documented because conducting and recording interviews properly would create logistical

problems. However, the researcher found the notes enlightening. The non-numerical nature of the data indicated that a qualitative research method was needed (Sukalmolson n.d., Neil 2007). Furthermore, the researcher's use of written responses for data collection coupled with the limited personal notes is in line with the recommended ways of collecting data in qualitative research. These are used for written descriptions by participants, verbal descriptions about participants' experiences of some phenomena (Neill 2006:2). Included also is the use of audiotapes and video taping of observations in the study (Fraenkel & Wallen 1990:373, 380).

The qualitative research method would not suffice for research question 3. The question involved finding out about the possibility of any relationship between learners' ability to identify science process skills and their achievement in performing these skills. A response to this question required marks for performing the skills and marks for identifying the skills. The data are numerical. Sukamolson (n.d.) explains that when a research study tests a hypothesis on the relationships of variables, or quantifying variables, a quantitative research method is recommended. Therefore in this study, a quantitative research method is needed to respond to research question 3.

The numerical and non-numerical nature of data in this study demanded the use of quantitative and qualitative research methods to complement each other. It was thus important to use both qualitative and quantitative research methods for the study.

3.4.3 INTERNAL AND EXTERNAL VALIDITY

Internal validity involves explaining the results of a research study in terms of the effect of the expected variables in the study. When the results are influenced by other unexpected variables, their effects on the research study are called threats to the internal validity of the research. The following serve as examples of threats: the effects of the characteristics of learners, loss of subjects in a study called mortality, location where the study takes place, testing procedures, historical events, maturation of subjects, implementation of the study and instrument decay coupled with the characteristics of a data collector (Fraenkel and Wallen, 1990:214-220). For example, in a study to establish the effect of a chemical in treating malnutrition in people, the people take food supplements in addition to the chemical under study without telling the researcher. The improved health status of the people cannot be ascribed to the chemical alone, but also to the food supplements. In this research study, some threats to internal validity are controlled. The mortality of subjects was controlled probably because of the short time of the study (four months) and the motivation subjects had to prepare for their external IGCSE examinations later in the year. Threats due to instrument decay and data collector characteristics were controlled by having the collection of data done by the researcher alone and analysing the non-numerical data and marking and scoring learners' worksheets. Threats due to testing were controlled by using separate sets of questions that were similar in structure but testing the same science process skills. But learners' preparation for their external examinations could have motivated them to use some of the past questions for practice. This was not obvious to the researcher. The threat posed by the maturation of learners was controlled by doing the research in a short period of time (four months). Although the short time factor may have minimised

physical maturation, it is possible that learners could experience cognitive maturation due to learning other subjects in the curriculum. A threat due to the implementation of the study did not arise because it was a case study of one group only and only one researcher was involved. The researcher was the subjects' teacher in Physical Science and therefore the presence of the researcher would not change conditions.

External validity, on the other hand, occurs when results of a research study can be generalized to the population from which the sample is selected. Variables that can affect the generalisation of the research findings are characteristics of the population (population generalisability) and difference in settings for the studies (ecological generalisability). External validity can be achieved by appropriate sampling to make the sample representative of the population and by conducting the same research in different settings and conditions. When these variables are not considered threats to external validity occur (Fraenkel & Wallen 1990:82-3). In this research, only one group case was used as a sample because the researcher was interested in an in-depth study of variables in the sample in order to gain some insight in how learners internalise science process skills. The question regarding the generalisation of the research results does not arise until the study is replicated in different locations and different settings. However, the results do apply to the school because the sample is in the school and other schools in similar situations.

3.5 INSTRUMENTS

The researcher, who was the Physical Science teacher of the learners participating in the study, developed and administered three types of instruments. A description of each type of instrument and its development follow next.

3.5.1 DESCRIPTION AND DEVELOPMENT OF INSTRUMENTS

All instruments could have been constructed from scratch but only the list of science process skills was prepared this way.

3.5.1.1 List of science process skills

This instrument was a learners' worksheet showing a list of Basic Science Process Skills and Integrated Science Process Skills. Learners in groups were required to write scopes and criteria for each science process skill.

In developing the instrument, it was imperative that all the basic and integrated science process skills recommended for school science curricula were listed.

3.5.1.2 Learners' group worksheets

These worksheets had instructions and questions for experiments and/or for processing scientific information on four IGCSE Physical Science topics. Learners used these worksheets in all the Physical Science lessons in the intervention phase. Three points were considered in developing these worksheets. Firstly, the content taught in this phase was extracted from the IGCSE Physical Science syllabus. Secondly, learning experiences obtained during instruction addressed assessment objectives stated in the syllabus.

Thirdly, each recommended science process skill was performed often enough in experiments/practical activities and related tasks.

3.5.1.3 Learners' individual worksheets

Two worksheets were developed on different IGCSE Physical Science topics. Both sets of worksheets contained adapted questions used mostly for the written paper 6, called Alternative to Practical mentioned in chapter 1, section 1.2.2 page 7. One worksheet was to be used in pre-intervention data collection. The other worksheet was used in the post-intervention data collection. The design of these questions tested learners' "familiarity with laboratory based procedures" (University of Cambridge International Examinations 2004:3). The procedures entailed performing science process skills. Consequently, questions on the worksheets required learners to identify science process skills performed in each part of any question. A few additional questions were representative of the IGCSE Physical Science paper 1 (multiple choice) and paper 2/3 (structured questions). Examples of questions in paper 1 is question 3 on the phase 1 individual activity (Appendix B) and questions 3 and 4 on the phase 3 individual activity (Appendix C). Table 3.1 shows how questions and marks are distributed on the two worksheets for each science process skill. Learners did not have access to this information.

Table 3.1 Question numbers and marks for each science process skill

SKILL		measuring	inferring	predicting	Using numbers
PRE-	Question number	2a	1a,b,d,e; 4aii	4ai	2e
PRE-	Marks perform	2	5	3	2
PRE-	Mark identify	1	5	1	1
POST-	Question number	1a	1a,b,c; 2b,c,d; 3; 4;5a; 6c; 7aii,b,cii,ciii	1ciii	1cii
POST	Marks perform	3	29	1	1
POST	Marks identify	1	17	1	1

SKILL		operation definition	interpreting	formulating hypotheses	experimenting
PRE-	Question numbers	1e	1f; 2cii,d; 3;4aii	4aiii	1g; 2f;
PRE-	Marks perform	1	9	3	7
PRE-	Marks identify	1	5	1	2
POST-	Question numbers	7ci	1a,b,c; 2b,c,d; 3; 4; 5a,bi,bii, ci, cii; 6c; 7cii	7aii	1cii; 2a; 6b
POST	Marks perform	2	29	2	10
POST-	Marks identify	1	15	1	3

Key: PRE- for pre-intervention POST- for post-intervention

Marks perform: marks awarded for performing the skill

Mark identify: marks awarded for identifying the skill

In the table, a column with experimenting at the top has the following information. 1g; 2f that are question numbers on the pre-intervention worksheet. The number 7 is the total number of marks that can be awarded for performing the skill of experimenting in the questions. The number 2 is the total number of marks awarded for identifying the same skill. The pattern is the same for each column and for each skill. There are two sets of three rows in each table. The top three rows have PRE- to show pre-intervention phase. For example, in the first row of the top table, there are question numbers for each skill, thus 2a for measuring, 1a, b, d, e, and 4aii are for inferring; 4ai for predicting and 2e for using number relationship. The pattern is the same for all columns.

In the development of individual learners' worksheets existing past IGCSE examination questions were utilised because this research was about science process skills in the IGCSE Physical Science syllabus, therefore, assessment items used for the syllabus are considered most suitable. However, past IGCSE Physical Science examination papers could not be used in full because they were long. A few questions were therefore selected without modifying the content and the science process skills embedded in them. When selecting the questions, frequency of any skill in the instrument was to be representative of its frequency in the IGCSE question papers. For example, skills of inferring and interpreting data had more questions than skills of predicting, defining operationally and using number relationships.

3.5.2 PROCEDURE FOR COLLECTING DATA

The description of science process skills was expressed in words in the form of scopes. Therefore the data are qualitative and the assessment of this data

must be qualitative. The researcher felt that the articulation of each skill would provide evidence of readiness to identify the skills in any task. The result was a pre-intervention and a post-intervention scope of each skill. The researcher kept limited personal notes and comments in all sessions concerning learners' actions and conversations. This data too were expressed in words.

When marking each question on learners' individual worksheets, performing and identifying science process skills would be considered separately. For performing a skill, marks would be awarded for method/explanation and other marks for accuracy (content wise and numerically). For the identification, each part of a question would be given 0.5 marks for stating the science process skill performed and another 0.5 mark for stating the criteria for the skill. These marks were not divisible. One set of scores were for pre-intervention numerical observation and the other set was for the post-intervention observation.

3.5.3 VALIDATION OF INSTRUMENTS

Validation of instruments was done in two stages, moderating the questions and piloting the instruments.

3.5.3.1 Moderation

Moderation was done by a group of five people with experience in the teaching of Physical Science. Two people were teacher trainers working with Physical Science teachers. Two were secondary school Physical Science teachers with more than 15 years teaching experience in the subject. One was a teacher advisor for Physical Science. Several proposals were made, which

the researcher implemented. The first was to include questions representative of all three IGCSE Physical Science question papers, thus, paper 1 (multiple choice), paper 2/3 (structured questions) and paper 6 (Alternative to Practical). This ensured coverage of all assessment objectives of the syllabus. The second was to include questions on content outside the four IGCSE Physical Science topics taught during the intervention phase. This acknowledged that science process skills are transferable to all topics in the syllabus. The moderators ensured that all factors considered in describing the development of instruments were implemented.

3.5.3.2 Pilot of instruments

Instruments were piloted in a school similar to the one hosting the study. Learners came from the Caprivi region and therefore ethnically, culturally and linguistically similar to learners in the sample. The school offered the same IGCSE curriculum that encompassed the Natural Science field of study in which Physical Science was one of the six subjects. Facilities in this school (science laboratory, science equipment and supply of chemicals) were comparable to the school hosting the study.

Two teachers and eight learners participated willingly in the pilot. The interaction in the group generated much interest in the topic of science process skills. This required more time than originally allocated. While both teachers and learners felt that the language in the instrument was comparable to IGCSE past examination questions, they made three proposals which the researcher implemented. (1) The time allocated to activities in all instruments was inadequate and they proposed that more time be allocated. The writing of scope of science process skills in phase one was singled out. Four one-hour

sessions were recommended to be done on four consecutive days within a period of one week. (2) Learners experienced difficulties with the concept of criteria as it related to science process skills. The recommendation was that learners ought to have a clear understanding of the concept. Therefore a researcher was to explain this concept to learners clearly. (3) Learners needed to be informed that if they identified a skill which was not in the list of recommended skills, the skill ought to be stated together with the criteria used.

Having noted all observations and suggestions, the researcher modified the instruments. Suggestions impinging on the administration of instruments were implemented during the three phases.

3.6 SAMPLING

Sampling is a process in research whereby a small group that forms part of the larger group is identified. The small group is called a sample from which information is obtained. The larger group is a population to which research results can be applied (Fraenkel & Wallen 1990:62). The sampling in this study is considered in three sections.

3.6.1 DEMOGRAPHIC BACKGROUND

This research was conducted at a school in the Caprivi region. Caprivi is one of 13 administrative regions of Namibia. It is an education region as well, with its regional administrative centre at Katima Mulilo town. Caprivi's inhabitants numbered 79, 826 in the census done in 2001 (National Planning Commission 2003: 4). This number represented 4 per cent of the total inhabitants of Namibia (Nation Master.com 2003-5:2) which stood at

2,088,669 (as of May 2008). The inhabitants in Caprivi formed part of a black population that constituted 87.5 per cent of the national inhabitants (CIA 2008: 2). Since 92 per cent of land in Namibia is desert (arid and semi-arid land), 67 per cent of the national inhabitants resided on communal land. The majority of these were black, concentrated in seven northern regions, namely Caprivi, Ohangwena, Okavango, Omusati, Otjozondjupa, Oshana and Oshikoto (National Planning Commission 2002: 5).

3.6.2 EDUCATIONAL BACKGROUND

The school that hosted the research study opened its doors to first learners in 1964 when it operated as a teacher training college. Since then it has become one of the senior secondary schools that experienced a change of curriculum by the government of Namibia, moving away from a South African curriculum to IGCSE after independence in 1990. The school with a yearly enrolment of about 500 learners was served by about 24 teachers who implemented curricula for both junior secondary phase and senior secondary phase. For the senior secondary phase the school offered three fields of study at the time of this study. These fields were Commerce, Home Economics and Natural Science. Learners in the sample for the study were enrolled in the field of Natural Science in which Physical Science was one of the six subjects. Teaching Physical Science at senior secondary level requires appropriate facilities. At the time of this research study, the school had satisfactory facilities which included a science laboratory, science equipment and an adequate supply of chemicals. The process of equipping the school with appropriate and sufficient equipment and adequate supply of chemicals took a long time. It started in about 1998. The facilities were used by all Physical Science teachers in the school and were accessible to all learners learning

Physical Science. The use of the laboratory was a must for lessons that involved learners in practical work/experiments. The researcher's experience at this school indicated that, at the time of the study, the school's facilities were comparable to only a few of the schools in Namibia, especially in the northern regions of Namibia.

3.6.3 SAMPLE

For this study the sample consisted of 34 learners in grade 12 constituting one class at one urban senior secondary school. This sample was purposive.

Fraenkel and Wallen (1990:67-68) explain that a purposive sample is identified based on the researcher's knowledge coupled with what the researcher intends to find out in the research study. The researcher was to find out how learners in one class would internalise science process skills in science instruction. The researcher considered such a finding to be significant insight for further research in teaching science in the Caprivi region and the rest of Namibia.

Four characteristics of interest to the researcher are discussed. Firstly, all learners in the sample were black. Ottevanger et al (2005:37) indicated that prior to Namibia's independence in 1990 black people were marginalised in education. The black learners usually did not study science and mathematics beyond junior secondary education. Teachers at the school that hosted the study were black. It is likely that when they were in secondary education, some of these teachers were taught by poorly trained black teachers. Putting this in context, Van Graan and Leu (2006:10) found out that in Namibia's pre-independence era, teacher training was based on racial lines. White student teachers were trained in the best equipped college in Windhoek. This college

was the one used as the University of Namibia at its inception after independence. Coloured student teachers were trained at a satisfactorily equipped college in Khomasdal. In contrast, black student teachers were trained at three satellite campuses in northern Namibia. Two of the three campuses were fused with secondary schools. These campuses had poor facilities and the failure rate was about 40 per cent. At the time of this study the school was continually aspiring to have well trained teachers in science.

A second characteristic is that since independence, learners' achievement in Physical Science had been low for several years. As a Physical Science teacher in the school, the researcher was curious to find out learners' knowledge of science process skills. The idea was more of interest because these learners were to write external IGCSE Physical Science examinations at the end of the year.

A third characteristic was that the sample was appropriate and convenient. The appropriateness came about because the research method involved one case study implementing a mixed qualitative and quantitative approach that generated numeric and non-numeric data. The convenience came about because the researcher was a teacher at the school. As a result, learners did not lose their learning time during the study. In addition, the researcher had ample time for an in-depth observation of learners. It also ensured that learners were being observed in their familiar learning environment. This removed distraction of learners by a researcher's presence. A further convenience was logistical in nature. The proximity of the sample and a researcher in the same location minimised the travel costs to conduct the research.

A fourth characteristic is that this sample has elements of most conditions described in the background to the study in chapter 1 section 1.1. The teaching of Physical Science in schools still needs to improve. At the time of the study, the Namibia government demonstrated its commitment by having Vision 2030, a policy framework for long-term development, in place. This scenario rendered the sample suitable for the case study.

The sample is not representative of learners studying Physical Science in the Caprivi region, but similar schools can be found in the Caprivi region and the remaining regions in Namibia. This is because there are differences in learner characteristics, sufficiency of facilities, teacher qualifications across schools in Namibia which can threaten the external validity of the results. Therefore research results of this study cannot be generalised to beyond the school that hosted the study. However, this study can provide suggestions for other schools in similar situations.

3.7 ADMINISTRATION OF INSTRUMENTS AND COLLECTION OF DATA

Instruments were administered in three phases. The phases were called pre-intervention, intervention and post-intervention. Small group work was used in pre-intervention and intervention phases to engage learners in social constructivist learning in which learners interacted with materials and peers as they co-constructed their knowledge (University of Sydney Department of Education and Social Work 2003:8). Such an arrangement enabled learners to perform the science process skills which “can only be inferred from actions, such as verbal and written responses, even in situations where the skills have

been taught explicitly” (Ogunniyi & Mikalsen 2004:152), as was the case in this study.

3.7.1 PRE-INTERVENTION PHASE

This phase started with a plenary session with all learners present in the class. Discussions aimed at making learners aware of their role in the activities of this study and how lessons were to be conducted. All sessions were conducted in a Physical Science laboratory. The learners were then arranged into eight groups of four and these groups were used for all group work activities.

Four activities were conducted. In activity 1 each group was given a worksheet showing a list of Basic Science Process Skills and Integrated Science Process Skills (appendix A). In each group learners used their past knowledge of the skills to write scopes for each skill and criteria for it. During the task learners were allowed to interact within and between the groups and their teacher (researcher) visited each group to ensure that all learners were clear about the task. Four one-hour sessions were used in one week, having one session per day on four consecutive days. Data from this task was a copy of the same list of skills but with scope and criteria written for each skill. The data were non-numerical and expected to reveal learners’ level of articulation of the skills which they had prior to intervention.

Without discussing learners’ group scope of skills done in activity 1, learners worked on activity 2. The worksheet had three tasks. In task 1, learners performed an experiment in which two clear liquids were mixed. Learners described the results of the experiment and then named a science process skill which they felt they had performed during the experiment. Learners provided

criteria to confirm the presence of the skill. In task 2 there was an incomplete table of results of an experiment showing volumes of water in a burette as the water was flowing out of the burette. Learners completed the table, plotted and interpreted a graph of the remaining volume of water in the burette against time. The task included questions for learners to answer. Using their scopes of skills done in activity 1 of this phase, learners identified skills which they felt they performed in the task. In task 3 learners in their groups carried out several experiments to show how length and diameter of an electric conductor wire influence its resistance to the flow of an electric current. The last question was about metals. The learners were given appropriate pieces of apparatus. Here again learners identified science process skills they felt they performed in each part of a task. Having participated in all tasks for activity 2, learners had performed all the science process skills listed in the literature review. What mattered was whether the learners themselves were able to identify all the skills. The outcome of activity 2 was a refined scope of the science process skills for each group.

In activity 3 each learner answered questions on a worksheet (Appendix B) individually. All questions required learners to be familiar with laboratory procedures, a condition stipulated for IGCSE Physical Science questions, especially in paper 6 called, Alternative to Practical (University of Cambridge International Examinations 2004:3). Consequently, there were no questions on the worksheet requiring learners to conduct experiments. After answering each part of a question, learners used their group scopes of the skills to identify skill(s) performed when answering each part of the questions.

The end of phase 1 was activity 4 which was a plenary session. Groups of learners reported on their work to the whole class, followed by a discussion. The outcome of the plenary session was two sets of data. One set was the qualitative description of scopes of the listed science process skills. This data formed a collective learners' articulation of the science process skills which they held prior to intervention. The other set was the quantitative numerical scores from performing and identifying science process skills embedded in tasks done so far. Both quantitative and qualitative data formed baseline information in the study. This means that the data were used as a reference point, to be compared to similar data collected in tasks done after intervention. The comparison helped to determine learners' improvement in articulating skills and achievement in performing and identifying science process skills.

3.7.2. INTERVENTION PHASE

This phase encompassed the teaching of four content topics of IGCSE Physical Science syllabus. These topics were chemical reactions and organic chemistry from the chemistry section of the syllabus; then electricity and magnetism and properties of waves, including light and sound from the physics section. Learners, in the same groups, performed practical/experimental tasks outlined in the group worksheets, based on the content of the four topics in the IGCSE Physical Science syllabus. This included planning, carrying out experiments and interpreting experimental data. Appropriate apparatus was provided to the learners. Table 3.2 shows a summary of the topic content covered in the lessons.

Table 3.2 Summary of topic content for lessons in intervention

CHEMISTRY SECTION	PHYSICS SECTION
<p>Chemical Reactions</p> <ul style="list-style-type: none"> - Production of energy - Energetics of a reaction - Speed of reaction - Redox <p>Organic Chemistry</p> <ul style="list-style-type: none"> - Names of compounds - Fuels - Homologous Series - Alkanes - Alkenes - Alcohols 	<p>Properties of Waves, including light and sound</p> <ul style="list-style-type: none"> - General wave properties - Light (a) Reflection of light (b) Refraction of light (c) Thin converging lens (d) Electromagnetic spectrum - Sound <p>Electricity and Magnetism</p> <ul style="list-style-type: none"> - Simple phenomena of magnetism - Electrostatics Electric charge - Electricity <ul style="list-style-type: none"> (a) Current (b) Electro-motive force (c) Potential difference (d) Resistance (e) V/I characteristics graphs - Electric circuits - Practical circuitry <ul style="list-style-type: none"> (a) Uses of electricity - Safety considerations - Electromagnetic effects <ul style="list-style-type: none"> (a) a. c. generator (b) d. c. motor (c) Transformer

University of Cambridge International Examinations 2004:5-6, 9, 12-14.

Teaching the four topics shown above was done for a period of 18 weeks with each lesson lasting 60 minutes on average. In conducting these lessons the teacher (the researcher) applied a constructivist view of teaching science

mentioned by the learning theories. In particular, learners worked cooperatively in the same groups of four for all lessons. Learning experiences in the groups included planning investigations, identifying apparatus suitable for the experiments, conducting planned experiments and interpreting experimental data. During all these tasks learners were motivated to verbalise (discuss) science process skills during the lesson. They were also encouraged to have debates in groups to convince each other of which skills were performed in the tasks. Verbalisation is supported because group members feel that it promotes “open discussions of view points” (Kelly et al n.d.). The verbalisation in groups “provides students with public forum for both testing their knowledge and extending and expanding it” (Hand & Vance 1995:41). Sometimes such discussions led to repeating some experiments with extensive use of scientific reference materials by learners in some groups in order to confirm the identified skills. In other cases learners replayed their roles in the tasks. After each lesson, before proceeding to the next lesson, there was a plenary session that usually lasted between 30 to 40 minutes. This is because the discussion of each lesson led to the continual refining of the articulation of the scope of science process skills. The premise for teaching these lessons was that skills can be used in teaching content of different topics as described in the Assessment Standards for grades 10-12 for outcome 1 in the National Curriculum Statements for Physical Science (Department of Education 2003:18, 19). The outcome of this phase was that learners’ final scopes of science process skills were more articulated compared to those done earlier on.

3.7.3 POST-INTERVENTION PHASE

In this phase learners used their final refined scope of science process skills (from intervention phase) to answer the last set of adapted IGCSE Physical Science examination questions (appendix C). This was individual work where learners answered questions on their individual worksheets. They identified science process skills performed in each part of the question and stated criteria for the presence of particular science process skills in the tasks. The quantitative numerical scores from this phase are presented in chapter 4.

In order to assess any change in learners' achievement in identifying and performing each skill, pre-intervention and post-intervention marks for each skill were to be expressed as percentages and compared. In addition, correlation coefficients for each science process skill were to be computed in order to establish if any relationship existed between learners' abilities to identify and perform science process skills.

3.8 SUMMARY

In this chapter research questions focus on whether learners were able to identify, with criteria, science process skills implied in their IGCSE Physical Science syllabus, and if any relationship existed between learners' abilities to perform and identify science process skills.

Both qualitative and quantitative research methods were used for the research in a One Group pre-post research design in which learners in one Namibian senior secondary school performed and identified science process skills during Physical Science lessons. The researcher (also the learners' Physical Science teacher) developed and used three types of instruments. The first one was a

list of science process skills for writing pre- and post- intervention scopes of the skills. The second one was a learner's group worksheet used for lessons during the intervention phase. The third one was a learner's individual worksheet for pre- and post-performance and identification of science process skills. The procedure of data collection included the allocation of marks for each skill and how qualitative data of scopes of science process skills and quantitative data of marks for performing each skill would be processed. Details of the analysis and a discussion of the data led to key findings of the study.

CHAPTER 4

ANALYSIS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

In this chapter qualitative and quantitative data from research activities are analysed and discussed leading to the formulation of the key findings.

4.2 QUALITATIVE DATA

Data are analysed in two ways. Firstly, pre- and post-intervention articulations of science process skills are reported respectively and compared. The articulation was done by learners describing scopes of skills from their perspective. Secondly, the learners' post-intervention scope is compared to the articulation of the same skills from the literature reviewed for this study.

4.2.1 LEARNERS' SCOPES OF SKILLS

Table 4.1 contains information about learners' response such as "no idea/never heard of it" to some science process skills in the pre-intervention individual work sheet.

Table 4.1 Percentages of learners responding with "no idea/never heard of it"

Name of science process skill	Group number	Number of learners	Percentage of learners %
Using number relationship	1,2,3,4, 5, 6,7,8	34/34	100
Operational definition	1,3,4, 6,8	21/34	62
Formulating hypotheses	1,2,3, 5,7	21/34	62
Identifying and controlling variables	3,6,8	13/34	38
Generalising	2,3,8	12/34	35

The learners' responses in the table should be read with learners' pre-intervention scopes of skills below.

Observing

Is looking carefully at certain action or an experiment happening and be able to explain what you have seen. For example the boiling point of water, the readings of the thermometer will rise to 100°C , bubbles will be seen.

Measuring

Is finding or taking actual amount of an object for example the length, width, height, mass, weight using instruments with units.

Classifying

Is the grouping or sorting of things for identification according to their properties.

Communicating

Is sharing ideas or exchanging of ideas between people for example dialogue, letters, SMS, NamPost (Namibia Post), sign language, body language (signs).

Inferring

Means to focus to something, thinking, or studying results to see what you can find out from them.

Predicting

Is to guess or estimate the result of something before it happens for example stating what will happen in 2010.

Using number relationship

No idea / never heard about it.

Operational definition

No idea or explaining the words in science the way they operate.

Formulating hypotheses

No idea, never heard about it, or suggestion or guess that tries to explain something

Identifying and controlling variables

Never heard about it or stating differences between substances such as bases and acids, non-metals and metals.

Collecting data

Is the gathering of information during experiments.

Interpreting data

Is the presenting of information in an understandable way. An example is recording information on a data sheet.

Generalising

No idea or make a statement of something without mentioning details.

Experimenting

Is conducting a practical work that involves observation and conclusion

The level of articulation of scopes of skills reveals that in general, learners had some knowledge of some skills. Learners' scopes had the basic elements to show meanings of skills of observing, measuring, communicating, inferring, predicting and interpreting data. Most of these are basic science process skills. The skill of experiment seemed to refer to conducting experiments only in which observations are made and conclusions made. In general the scopes provided lacked details. For the remaining skills reference should be made to both table 4.1 and learners' pre-intervention scopes of skills. A 100 per cent for the skill of using numbers meant that all learners said they had no idea or they had never heard about it. For each of the skills of operational definition and formulating hypotheses, 62 per cent of learners said they had no idea/never heard of it. Thirty eight (38) per cent and 35 per cent said they had no idea/never heard about it for skills of identifying and generalising respectively.

Furthermore, information about group numbers in table 4.1 reveals that group number 3 experienced difficulties with all skills, seconded by group 8. The examination of individuals in these groups indicated that these learners had joined the school after their junior secondary education. It is possible that these learners did not learn basic skills in grade 8 although the skills were in the syllabus. Beyond grade 8 skills did not form part of the syllabus. However scopes for some groups contained details. It is probable that learners in these groups might have researched the skills in between group sessions.

After intervention learners again wrote scopes, details of which are next.

Observing

The process of watching, seeing, noticing and understanding what is going on in an experiment using the senses of sight, touch, hearing and smelling. Evidence of observing is for example using sight to state the change of colour in an experiment.

Measuring

Is the finding out of mass, height, length, weight etc of objects using instruments with units on them and the amounts must have units.

Classifying

Is the sorting or grouping or arranging of things according to their characteristics such as types, properties, sizes, ages, states of matter, groups of pens, separation of metals from non-metals on the periodic table by a zigzag line, arranging things alphabetically.

Communicating

Is the exchanging or sharing of ideas or discussing ideas using media (telephone, SMS,); verbally; in written form; and body language (signs).

Inferring

Is the studying of results of an activity such as an experiment to decide if the facts are true based on information one has. Evidence is the explanation of the outcome of the experiment.

Predicting

Making a sensible guess of results of an activity before it happens. For example when heating the bimetallic strip the teacher asks us to describe what we think will happen to the strip after heating. The description is done before the heating of the strip starts.

Using number relationship

Is the converting of information into numerical form, for example, the radioactive decay of isotopes can be shown by series of numbers. It is also the relationship between numbers, for example, the distance-time graph to show the speed of any moving object. Evidence of this skill is the presence of calculations with units.

Operational definition

Explaining words in science the way they operate. Evidence is the presence of explanation of the meanings of the words.

Formulating hypotheses

Is to express a suggestion or a guess that tries to explain about an experiment.

Identifying and controlling variables

Stating differences between things that influence an experiment, for example, the effect of the length of a conductor wire on its resistance, or the effect of the concentration of an acid on the rate of a reaction in which the acid is used.

Interpreting data

Is the presenting of information or ideas in an understandable way such as from an experiment by reading from apparatus and recording it on a data sheet. It is also a collection of information from an experiment such as reading and recording of information onto a graph, or from tables onto a graph; or the summarising of information. Evidence is the presence of constructed formulae, plotted graphs or constructed tables of data.

Generalising

Is to make a statement about something without mentioning any details

Experimenting

A scientific test such as a practical activity in which apparatus is used, observations are made and conclusions done. It can be a process in which one tries to find out if a new idea or method is effective or planning how to conduct an experiment which includes: identification of apparatus, description of the procedures and the prediction of the expected results. Evidence is the presence of numbers, plans of experiment, and use of apparatus.

Scopes of science process skills detailed above indicate that after intervention learners were able to write scopes for all science process skills. This included skills of using number relationship, operational definition, formulating hypotheses, identifying and controlling variables and generalising about which some learners had no idea prior to intervention activities. The analysis of scopes reveals learners' ability to describe processes which constitute each skill and provide evidence to confirm the presence of the skills. One example is the process of reading from apparatus in an experiment and recording the reading onto a graph, which forms part of the skill of interpreting data. Evidence shown for this skill includes a plotted graph or constructed tables of data.

Learners' post-intervention scopes of skills and scopes of the same skills but from literature reviewed, show similarities. The two sets of scopes are comparable in content except for the skill of generalising which learners seemed to struggle with. Each science process skill comprises processes and products of the processes. Recognising that learners had no access to the scope from literature, the congruency of the post-intervention scope to the scope from literature suggests that the intervention was effective in enabling learners to improve their articulation of the science process skills.

4.3 QUANTITATIVE DATA

The discussion of quantitative data is not done in isolation because in this study quantitative and qualitative research methods complemented each other. Therefore reference is made to qualitative data (articulation of scope of skills) in the discussions that follow. Identification and performance of the skills were assigned marks in individual worksheets. Identifying any skill had two components, naming the skill and stating criteria for it.

4.3.1 IDENTIFYING SKILLS

Table 4.2 shows data about learners' marks attained for identifying science process skills by names and for stating criteria for the skills in written tasks on individual worksheets. The total marks for each skill are expressed in percentages.

Table 4.2 Percentages of marks for learners' identification and criteria for science process skills

Skill	measuring		inferring		predicting		using numbers	
Components	Id	Cre	Id	Cre	Id	Cre	Id	cre
Pre- (%)	47	6	38	22	60	27	33	33
Post- (%)	87	87	52	50	93	80	100	87

Skill	operational definition		Formulating Hypotheses		Interpreting data		experimenting	
Components	Id	Cre	Id	Cre	Id	Cre	Id	cre
Pre- (%)	40	40	53	20	43	31	33	10
Post- (%)	73	73	80	66	62	59	76	69

KEY: Id:- Identify, Cre:- Criteria, Pre:-Pre-intervention, Post:- Post-intervention

Table 4.2 shows that learners were able to identify and name eight science process skills in pre- and post-intervention individual written tasks. These skills are measuring, inferring, predicting, using number relationship, operational definition, formulating hypotheses, interpreting data and experimenting. Criteria were provided for all identified science process skills.

The researcher noticed learners' difficulty in verbalising skills during the first and second sessions of the pre-intervention activities. This was more noticeable when stating criteria for the skills. Despite learning and practising some basic science process skills when they were in grade 8, it still took learners time to recall what they had learnt.

The researcher further noticed that as learners got engaged in successive intervention activities, debates within and across groups intensified, involving each skill used in the tasks. Finally learners resolved to verbalise the skills as the particular skills in question were performed. The outcome of group work from learning the four Physical Science topic content was a progressively improved articulation of the skills. Easiness was observed in identifying the skills and in providing criteria for the skills. This trend was obvious from the researcher's personal notes and comments about the sessions. The improvement is supported by learners' attainment in the post-intervention individual tasks because the minimum percentage of learners' total marks attained for identifying any skill increased from 33 per cent (pre-intervention) to 52 per cent (post-intervention). For providing criteria, the minimum percentage of marks for the skills increased from 6 per cent (pre-intervention) to 50 per cent (post-intervention). The percentages suggest that learners' ability to identify skills and provide criteria for the skills were enhanced after

intervention. Therefore, the intervention was effective in improving learners' identification of skills and providing criteria for the presence of skills in the Physical Science tasks.

There were four characteristics of situations in which learners identified science process skills. Such situations were revealed by learners' responses on individual and group worksheets. The researcher's notes and comments enhanced these observations.

The first characteristic concerned skills of observing, measuring and communicating. These were identified in group practical tasks only and not in individual written tasks. Skills of classifying and generalizing are commented on. The following specific observations were made.

1. The skill of observing was identified in practical tasks (manipulation of apparatus) only.
2. The skill of measuring was identified in practical tasks every time, in which learners were required to read from a measuring device such as rulers, meters and thermometers.
3. The skill of communicating was associated with plenary sessions only, where groups of learners reported to the whole class.
4. Skills of classifying and generalising were not identified in any task, practical or written.

It seems that to engage learners in either practical tasks or written tasks on its own has a bearing on how learners perceive the same skill embedded in the task. Therefore Physical Science instruction should include both practical/performance and written tasks.

The second characteristic involved learners' use of multiple names for one skill embedded in a written task. The following are examples found on table 3.1 in chapter 3.

1. Question 1a of the post-intervention individual worksheet tested the skill of measuring. A few learners identified the skill as measuring only. The majority of learners called the skill as inferring/collecting data/interpreting data in addition to calling it measuring.
2. Question 7a ii of the post-intervention individual worksheet was assigned to the skill of formulating hypotheses. The majority of learners named the skill *formulating hypotheses*. About half of the learners named the skill *inferring* in addition to formulating hypotheses.
3. Questions 1c ii, 2a, and 6b on the same worksheet were assigned to the skill of experimenting. Learners' responses did name the skill as experimenting. Skills of collecting data and identifying and controlling variables were identified as part of the skill of experimenting. This seems consistent with the scope of this skill in the literature review of this study.

This characteristic requires curriculum developers, examiners and Physical Science teachers to be aware of learners' multiple names of science process skills especially in written tasks.

A third characteristic involved a skill learners identified which was not part of the list in the literature review. The skill was named *constructing* which was identified in situations where learners either arranged apparatus in practical tasks, or drew diagrams of objects such as molecules of substances, magnetic

field around a magnet and apparatus used in experiments. This was evident in learners' responses to questions 1c ii, 2a, 5a, b ii, 5 c ii and 6 c on the post-test individual worksheet. One example is a response to question 2a that demanded a drawing of apparatus. The other example is a response to question 5a that asked for a structural representation of hydrogen, H₂ molecule. All these questions required learners to draw diagrams of objects. The same response was evident during group practical/written tasks. Learners felt that these tasks required one's ability in spatial orientation of the objects which was not the same in other skills. Learners identified this skill consistently in all tasks that involved the arrangement of apparatus or drawing diagrams of objects.

A fourth characteristic relates to the hierarchical interrelationship of the basic and integrated science process skills. Learners' difficulties with articulating skills observed during the learning sessions were more noticeable with integrated science process skills. For example, the response of no idea/never heard it was recorded for integrated skills of operational definition, formulating hypotheses, identifying and controlling variables and generalising. Only one basic skill of using number relationship recorded this response. Despite showing skills under categories of basic and integrated skills, learners' responses in individual and group learning sessions did not seem to acknowledge the hierarchical interrelationship of the skills.

4.3.2 CRITERIA FOR SKILLS

Every time learners performed any skill in practical tasks and in written tasks, criteria had to be stated to confirm the presence of such a skill. The

information below is about learners' responses to state criteria for each science process skill identified in written tasks.

Observing: - stating results of an experiment
- stating change of colour
- using sight to see what is happening
- using sight to see the colour
- presenting information such as numbers with units

Measuring: - reading from measuring devices
- finding temperature with a thermometer
- using numbers with units

Inferring - studying results of experiments
- studying given information
- explaining outcome of experiment

Predicting - making sensible guess about the expected temperature
- guessing results of an activity

Operational
Definition - explaining meaning of words

Using number
Relationship - doing calculations
- converting readings from thermometer into numbers in a table
- presenting calculations with units
- showing relationship between numbers, for example volume-time graph

Formulating
Hypotheses - a guess that tries to explain an experiment

Interpreting
Data - obtaining information from plotted graph
- giving evidence from diagram into table
- collecting information from the thermometer and recording in a table

- collecting information from a table and presenting on a graph
- constructing tables of data
- constructing formulae
- plotting graph of data, for example temperature-time graph

- Experimenting
- do the experiment
 - showing how an experiment can be carried out
 - planning of experiments
 - using of apparatus
 - drawing of apparatus used in an experiment
 - recording of investigations to prove ideas

- *Constructing
- drawing diagrams
 - drawing a magnetic field around a magnet
 - presenting diagrams of objects such as 'dot' and 'cross' diagram of hydrogen, H₂ molecule

Two characteristics of criteria emerge from the data above. Firstly, criteria are processes that describe what learners experienced while performing the skills.

Three examples support this characteristic.

1. The process of either reading from measuring devices or finding temperature with a thermometer is written as criteria for the skill of measuring.
2. The process of having collected data from a table and presented the data on a graph is given as criteria for the skill of interpreting data.
3. The process of drawing magnetic field around a magnet is used as criteria for the learners' own skill of constructing.

There are a set of process criteria for all science process skills except for the skill of forming hypotheses.

The second characteristic is that some criteria describe tangible results of the processes mentioned in the first characteristic. Examples are in the data above.

1. Presence of numbers with units showing that the skill of measuring had occurred.
2. Presence of constructed tables of data, plotted graph of data such as temperature-time graph and information from plotted graph, all showing that a skill of interpreting data had been performed.

All the science process skills above have each a set of product criteria.

The two characteristics of criteria indicate that learners used processes and products of the processes as evidence to show that science process skills had been performed.

A comparison of learners' post-intervention scope of skills and learners' criteria for skills reveals some similarities. Both process and product criteria are inherent in the learners' post-intervention scopes of skills. The researcher's hunch is that the level of articulation of the science process skills provided learners with a way of describing processes and products as evidence of skills performed in the tasks.

4.3.3 ACHIEVEMENT IN PERFORMING SCIENCE PROCESS SKILLS

Every part of questions in practical and written tasks engaged learners in performing one or more of the science process skills listed in the literature for this study. Marks were awarded for acting out (performing) the skills. Marks were awarded also for identifying (criteria included) the skills. The marks for performing and identifying skills were expressed as percentages. Correlation coefficients were computed for each skill to establish whether any relationship

exited between learners' achievement in performing science process skills and their ability to identify the skills.

Table 4.3 is about pre- and post-intervention learners' percentage of marks for each identified science process skill. Correlation coefficients are shown for each skill in the last two columns of the table.

Table 4.3 Percentages of marks and correlation coefficients for science process skills

Skill	Performing skills		Identifying skills		Correlation coefficients	
	Pre- %	Post-%	Pre-%	Post-%	Pre-%	Post-%
Measuring	100	100	27	87	-	-
Inferring	88	68	30	51	0.04	0.01
Predicting	77	50	43	88	-0.16	0.55
Using number relationship	24	46	33	73	0.36	-0.10
Operational definition	17	97	37	87	-0.25	0.34
Formulating hypotheses	34	73	27	73	-0.06	0.50
Interpreting data	68	76	37	59	-0.01	0.13
Experimenting	50	60	43	77	0.07	0.56

KEY: Pre-: pre-intervention Post-: post-intervention

In columns for performing skills, learners' achievement in the skill of measuring is high and equal, suggesting that learners had no difficulty with the skill. The achievement in the skills of inferring and predicting decreased from pre-intervention to post-intervention activities. A possible explanation

could be the way marks were awarded for performing any skill. There were marks for acting out the skill and for accuracy in the content in which the skill is performed. In post-intervention tasks most learners were not accurate in content with their inferences and predictions. Learning science process skills and learning syllabus content in which skills are performed complement each other and are valuable (Rillero 1998:4). The goal of doing laboratory work is to enhance students' scientific knowledge. But there is a need for students "to have sufficient content knowledge related to the investigations in order for them to engage purposefully with their laboratory work"(Berry et al 1999:31). Therefore learners in this study needed to have sufficient knowledge of content in which the science process skills of inferring and predicting were performed. For the remaining identified skills in table 4.3, learners achieved higher in performing the skills after intervention than before intervention. This is an indication that the intervention was effective in enhancing learners' performance of the skills. In columns for identifying skills, learners performed better in all identified skills after intervention than before intervention. It seems that intervention enhanced learners' ability to identify skills listed in the literature for this study. Correlation coefficients for all skills are low and negative in some cases. The exceptions are skills involving formulating hypotheses (0.50), predicting (0.55) and experimenting (0.56). These show post-intervention correlation coefficients between 0.5 and 0.6 which suggests that after intervention there was some relationship between learners' achievement in performing and identifying skills of formulating hypotheses, predicting and experimenting only.

4.4 KEY FINDINGS OF RESEARCH STUDY

Below is a summary of the discussion of research results to highlight focal points.

- Learners were able to identify science process skills in their IGCSE Physical Science after learning the skills during the instruction of this subject. Some of the skills were identified only in practical work/experimental work. One skill was discovered by learners during group and individual work. Some skills were identified as subsets of others. Two skills that were listed in the literature review were not identified by learners. One skill was associated with plenary sessions only.
- Learners did not display any evidence that they were aware of the hierarchical nature of basic and integrated science process skills.
- The process of identifying a skill seemed to be a product of simultaneous performance and verbalisation of the skill in a task.
- The structure of learners' scopes of science process skills was similar to the structure of scopes of the same skills in the review of literature for the present study. A hunch was that the level of articulation of the science process skills provided learners with a way to identifying the skills.
- Learners provided criteria for the science process skills performed in research tasks. Their criteria comprised of processes they experienced during the performance and products of those processes.
- Results showed that there seemed not to be any relationship between learners' achievement in performing skills and their ability in identifying the skills. The non-numerical observations seem to suggest

that performing, verbalising and articulating science process skills seem to precede the identification of the performed skills. There is a need to explore this phenomenon further.

4.5 SUMMARY

In this chapter data were analysed and discussed to highlight key findings listed above. Learners' articulation of science process skills improved after intervention. The process of articulating the skills enhanced continually in quality during the intervention. This suggests that internalising the articulation of skills is progressive. Key findings demonstrate that the intervention was effective. Learners were able to identify science process skills and provided criteria (evidence) for the identified science process skills. New phenomena were identified about relationship between variables of performing, verbalising and articulating science process skills that may influence the identification of the skills.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter provides the conclusion of the research findings and recommendations.

5.2 CONCLUSION

The research results of this study provide responses to the three research questions. The response to question 1 is that learners were able to identify science process skills in their IGCSE Physical Science syllabus after they were taught the skills. The response to question 2 is that learners' criteria for the skills were processes and products of those processes which they experienced during the tasks. The response to question 3 was that there seemed to be no relationship between learners' ability to identify skills and their achievement in performing the skills. Therefore the research achieved its intended aim. In addition, the results have revealed observations that confirm previous research results on some variables influencing science process skills in science instruction. The research results have also highlighted observations that require further exploration. Both aspects are discussed next.

There is consensus that science process skills are central to learning science. In line with results of this study, science process skills can be developed by teaching them to learners (Germann& Aram 1996:795; Chang 2002:448). The issue to discuss is how results of this research suggest variables that influence the teaching to develop science process skills. Several variables are handled.

5.2.1 APPLICATION OF CONSTRUCTIVIST LEARNING THEORY

The researcher's observations of group sessions revealed learners' intensive debates of ideas, conversations and verbalising their performances. These preceded the group's consensus on naming a skill that learners felt they performed in the given task. These observations seem to demonstrate principles of constructivist theory of learning. Hein (1996:2-3) describes that learners engage in an active mental process of constructing knowledge; that the process occurs in a social activity where learners use language in negotiating meaning in learning situations which include hands-on learning experiences. Bowen (1999:1040) also confirmed these observations in a study of interpretations of graphing by university Biology students. He suggests that learning the skill of interpreting graphs was achieved when the students participated in continuous interaction with peers and teachers. Therefore, constructivist learning theories should continue to form a basis for learning experiences in the development of science process skills.

5.2.2 INSTRUCTIONAL STRATEGIES AND TEACHER'S ROLE

In line with constructivist learning theories, learners should be engaged in collaborative and cooperative learning using group work. A research by Rapudi (2004:53) demonstrated how cooperative learning enabled learners to achieve skills of graphing and experimenting. In this research all learning experiences were done by group work with four learners in each group. The researcher, as teacher, made learners develop ideas through their learning experiences which persuaded them to interact with each other more than with their teacher. The teacher was performing the role of a teacher as a facilitator. From a theoretical view, Brewer (1971:4) recommends that in a constructivist classroom a teacher should focus on learner-centred experiences and the

teacher's role is to be a facilitator. Research studies on teaching and assessing several science process skills have recommended that teachers should provide appropriate learning experiences (Germann 1996:795; Chang 2002:442). The question at stake is whether teachers are adequately qualified to implement this role. This is the question lingering in the researcher's mind about science teachers in the northern regions of Namibia. Especially against the back drop of some teachers having limited conceptual understanding of cooperative learning and learner-centred education (Van Graan & Leu 2006:65, 87). It is suggested that teachers should first experience categorising the skills for their understanding of the skills before teaching the skills to their learners (Valentino 200:3). Harlen (1999:142) suggests further that teachers be engaged in professional development and be supplied with manuals of instructional tasks.

5.2.3 TEACHING CONTEXT

The teaching context could refer to a discipline in which science process skills are developed. It could also refer to a problem situation. Observations in this study showed that some learners failed to perform skills of inferring and predicting because (the researcher felt) they did not have sufficient content knowledge about the topic involved. Rillero (1998:2-3) suggests that science process skills and content knowledge should complement each other in science instruction. The other suggestion is to teach science process skills in problem situations to develop learners' ability to solve problems (Valentino 200:3; Hein 1996:3).

5.2.4 HIERARCHY OF SKILLS AND LENGTH OF INSTRUCTION

Observations in this research indicated that most learners experienced difficulties in identifying integrated science process skills prior to intervention. It took learners more sessions of intervention instruction for the learners to achieve identifying integrated skills than basic skills. These observations are similar to those by Brotherton and Preece (1996:73) that intervention was effective on integrated skills but not basic skills. Learners had prior knowledge of basic skills but not integrated skills. The difference arose because learners' conceptual readiness to develop basic skills had already been achieved but not for integrated skills. By observing assessment skills Harlen (1999:141) concluded that it would require extended tasks in regular class work to develop some integrated skills. It appears that the learners' difficulties in this research were probably because they had already achieved their conceptual readiness for basic skills but not for integrated skills. The hierarchy of skills seems to have an effect on the length of instruction of science process skills.

5.2.5 ARTICULATING SKILLS AND PROVIDING EVIDENCE

In this research providing evidence referred to a tangible occurrence to confirm the presence of science process skills in a performed task. The evidence was called criteria. The researchers' observations revealed difficulties that learners experienced in grasping the meaning of criteria. It took several sessions for learners to begin to make sense of it. Results confirmed that the intervention was effective in achieving the skill of providing criteria for skills. Similar results were found by Bennett et al (2004:14, 15) who acknowledged that in a literature review of use of small groups discussions in science teaching, there was diversity in interpreting a

term of evidence and term of providing evidence. In a study on the assessment of science process skills, very few learners gave evidence of their tasks. Also, very few learners were able to provide evidence for their conclusions (Germann & Aram 1996:790). The results of this research seem to reveal a continual challenge of achieving the skills of evidence and providing evidence in science instruction.

In addition, specific to the research results of this study is the role played by articulating science process skills in writing criteria. The researcher observed that with the improvement in articulating skills, learners used processes and products of these processes as criteria for presence of the skills. The articulation was more elaborate when done simultaneously with the performance of the skill. In absence of any previous research to explore this phenomenon, this provides an opportunity for more research to explore any relationship among variables of articulating, performing and identifying science process skills with the provision of criteria for the skills.

In summary, theoretically the One Group Pre-test Post-test case study limits the applicability of the research results to the school that hosted the study. The reality is that the research results have succeeded to provide insights in how learners internalise science process skills which can apply to other schools in a similar situation. Some insights support variables recommended in previous research studies that positively influence the teaching of science process skills. Other insights provoke a need for conducting more research studies on different phenomena. This forms a premise for the recommendations discussed below.

5.3 RECOMMENDATIONS

5.3.1 IMPLICATIONS FOR INSTRUCTION IN SCIENCE

Recommendation 1

Learners should be taught science process skills in regular science classes. Learning experiences should include articulating science process skills. The articulation should be done in conjunction with the actual performance of the skills because this seems to aid learners to internalise the skills. Verbalising the performed skills should be encouraged and learners should provide evidence of all skills performed in tasks.

Recommendation 2

Learners should be afforded opportunities to propose names of science process skills they experience as long as the proposals can be justified by learners' own experiences in performing the skills. Specific to this is the need for engaging learners in interviews so that verbatim accounts can reveal justifications for the newly proposed names of skills as well as for multiple names for the same skill.

Recommendation 3

Learners should carry out all investigations stipulated in Physical Science syllabuses. This will ensure that learners practise all science process skills implied in the syllabus throughout their year of study. The investigations could form course work of the syllabus but considered as part of the final external examination assessment.

Recommendation 4

Physical Science teachers should engage learners in performing all identified science process skills when teaching content of each topic in the syllabus.

This would ensure that learners develop an understanding of scientific knowledge of the content in the syllabus through use of science process skills, since the literature shows that content and science process skills complement each other during science instruction.

Recommendation 5

Physical Science teachers should be engaged in school-based research on science process skills in order to teach the skills with confidence. Their participation in professional development programmes on the development of science process skills is also recommended.

5.3.2 IMPLICATIONS FOR FURTHER RESEARCH

Recommendation 6

There is a need to replicate this study by using a bigger sample in several different settings and locations and utilising verbatim accounts of learners' verbal utterings. A longitudinal research study is also recommended, to be done in junior secondary phase (grades 8, 9 and 10), results of which could provide more insight in how learners develop an understanding of science process skills.

Recommendation 7

Further research studies can be done to explore the following variables. To what extent learners' simultaneous performance and verbalisation of science process skills influence learners' identification of the skills? Why learners'

scope of science process skills and criteria (tangible evidence) used for identification share common elements in structure? And what form should teachers' professional development take to enable them to teach science process skills effectively?

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APPENDICES

APPENDIX A: ACTIVITY 1

GROUP NUMBER: _____ DATE: _____

PHASE ONE GROUP WORK SHEET

LIST OF SCIENCE PROCESS SKILLS IN SCIENCE CURRICULA

Instructions: You are required describe each skill in the spaces provided by writing specific action you would perform in a Physical science lesson. Include evidence (criterion) in the description that would confirm the presence of the skill.

BSPS

Observing

Measuring

Classifying

Communicating

Inferring

Predicting

Using number relationships

ISPS

Formulating hypotheses

Identifying and controlling variables

Generalizing

Collecting data

Interpreting data

Operational definition

Experimenting

APPENDIX A: ACTIVITY 2

GROUP NUMBER: _____ **DATE:** _____

PHASE 1 GROUP WORK SHEET

Instructions: In this activity as you perform any task, identify the **SPS** performed as well as describing the **CRITERIA** you have used in the identification process.

Task 1

Two clear solutions are in test tubes labeled potassium nitrate and lead iodide. Mix the two solutions in one of the test tubes.

(a) Describe what happens when the two solutions are mixed.

.....
.....

SPS

CRITERIA

.....
.....

(b) Give a reason for your answer

.....
.....

SPS

CRITERIA

.....
.....

Task 2

A learner conducted an experiment to find how the rate of flow of water through the tap of the burette depends on the volume of the water remaining in the burette. The results of the experiment are shown in the table below.

Time, T/s	0	20	40	60	80	100	115
Burette reading, R/cm ³	0	14.0	24.5	33.0	40.4	46.0	50.0
Volume of water in the burette, V/cm ³	50.0						

(a) Calculate and complete the third row showing the values of V.

.....
.....

SPS

CRITERIA

.....
.....

(b) On the grid, plot V against T. Draw a smooth curve through the points. (Graph paper is provided separately)

SPS

CRITERIA

.....
.....

(c) Use your graph to describe how the values of V change in relation to the values of T, state if the graph is supporting what the learner wanted to find.

.....
.....

SPS

CRITERIA

.....
.....

Task 3

You are to use the electrical circuit provided to find out how the resistance of a conductor wire (provided) changes when its length and cross section area are increased respectively. Additional materials can be requested if required.

1. Increasing the length of the wire.

(a) Variables in the experiment

(i) State variables that can influence this experiment.

.....
.....

SPS

CRITERIA

.....
.....

(ii) Of the variables listed above, state those that should be changed during the experiment.

.....

SPS

CRITERIA

.....

(iii) Those variables that should not be changed (controlled).

.....

SPS

CRITERIA

.....

(b) Carry out the experiment and write your results by filling the values in the table below.

Length /cm	Voltage /v	Current /A	Resistance /ohm

SPS

CRITERIA

.....

(c) Plot and draw a graph of resistance on the vertical axis against length on the horizontal axis using the values in the table. (Graph paper is provided separately)

SPS

CRITERIA

.....

(d) Use your graph to describe the effect of increasing length on the resistance of the wire.

SPS	CRITERIA
.....
.....

2 Increasing the cross section area

(a) Variables in the experiment

(i) State the variables that can influence this experiment.

SPS	CRITERIA
.....
.....
.....

(ii) Of the variables stated above, write the ones that should be changed during the experiment.

SPS	CRITERIA
.....
.....

(iii) Those variables that should not be changed (controlled) during the experiment.

SPS	CRITERIA
.....
.....

(b) Carry out the experiment and write the results in the table below.

Diameter /mm	Voltage /V	Current /A	Resistance /ohm

SPS

CRITERIA

.....

(c) Use the values in the table to plot a graph of resistance on the vertical axis against cross section area on the horizontal axis. Draw the graph through plotted points. (Graph paper is provided.)

SPS

CRITERIA

.....

Task 4

A cook intends to buy a pot. A store has aluminum pots, iron cast pots and copper base pots.

(a) Describe an experiment you would do to convince the cook on which pots would be suitable.

.....

SPS

CRITERIA

.....
 (c) Draw labelled diagrams of apparatus you would use in the experiment.

SPS

CRITERIA

.....

APPENDIX B

NAME: _____ YOUR LETTER: _____ DATE _____

PHASE 1 INDIVIDUAL WORK SHEET

Instructions:

Answer all questions in the spaces provided. Under **SPS** state a science process skill you performed when writing the answer and under **CRITERIA** write evidence in the answer that confirms that the skill you have indicated is present.

1. A student was told to analyse crystalline solid A, which contains two cations and one anion, using the flow shown in Figure 1.1, which contains tests 1 to 5. (2001 paper 6)

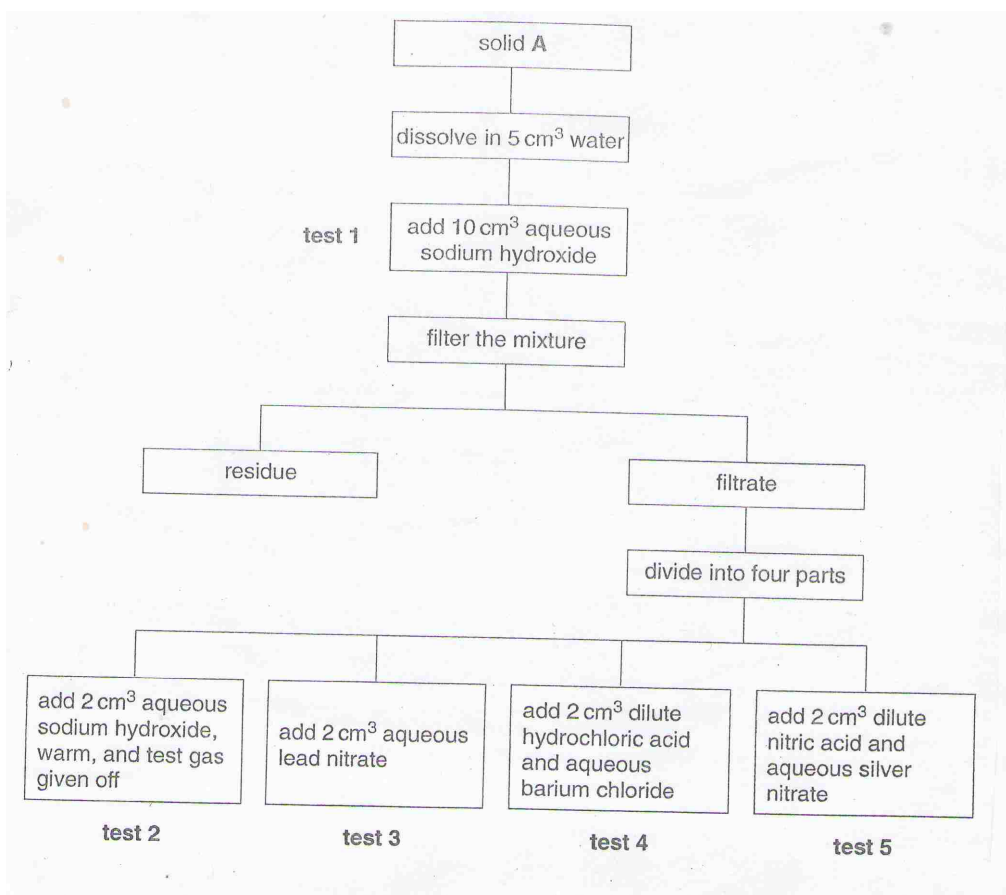


Figure 1.1

- (a) The residue from **Test 1** was green.
Suggest one conclusion which can be made from this observation.
.....
.....(1)
- | | |
|-------------------|------------------------|
| <u>SPS</u> | <u>CRITERIA</u> |
| | |
| ..... | .....(1) |
- (b) The gas given off in **Test 2** turned red litmus blue.
Name this gas.
.....(1)
- | | |
|-------------------|------------------------|
| <u>SPS</u> | <u>CRITERIA</u> |
| | |
| ..... | .....(1) |
- (c) A precipitate was formed in **Test 3**.
What is meant by the term precipitate?
.....(1)
- | | |
|-------------------|------------------------|
| <u>SPS</u> | <u>CRITERIA</u> |
| | |
| ..... | ..... (1) |
- (d) A white precipitate was formed in **Test 4**.
What can be concluded from this observation?
.....(1)
- | | |
|-------------------|-------------------------|
| <u>SPS</u> | <u>CREITERIA</u> |
| | |
| ..... | .....(1) |
- (e) A white precipitate was formed in **Test 5**.
What can be concluded from this observation?
.....(1)
- | | |
|-------------------|------------------------|
| <u>SPS</u> | <u>CRITERIA</u> |
| | |
| ..... | .....(1) |
- (f) Write the formula of one of the ions contained in solid **A**.
.....(1)
- | | |
|-------------------|------------------------|
| <u>SPS</u> | <u>CRITERIA</u> |
| | |
| ..... | .....(1) |

(g) Solid **A** contains water, which forms part of the crystal structure. This water is given off when solid **A** is heated.

Describe how you could carry out an experiment to determine the percentage of water in the sample of solid **A**. Indicate how the percentage of water can be calculated from the results of the experiment.

.....

(4)

SPS

CRITERIA

.....

(1)

2. A student did an experiment to find out how the force needed to move a slider along a horizontal surface varied with the weight of the slider. See Figure 2.1. (2001 paper 6 November)

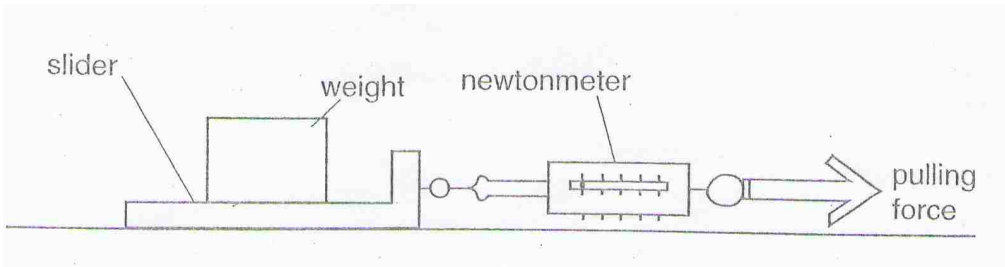


Figure 2.1

He placed a 5N weight on the slider. He pulled it along the surface at a steady speed and noted the reading on the Newton meter. He recorded the reading in the table, Figure 2.2.

weight added to slider / N	5	10	15	20	25	30
pulling force / N	1.1	1.8		3.4		4.9

Figure 2.2

He found the pull needed using weights up to 30N on the slider.

(a) Figure 2.3 shows the Newton meter scale using two of the weights.

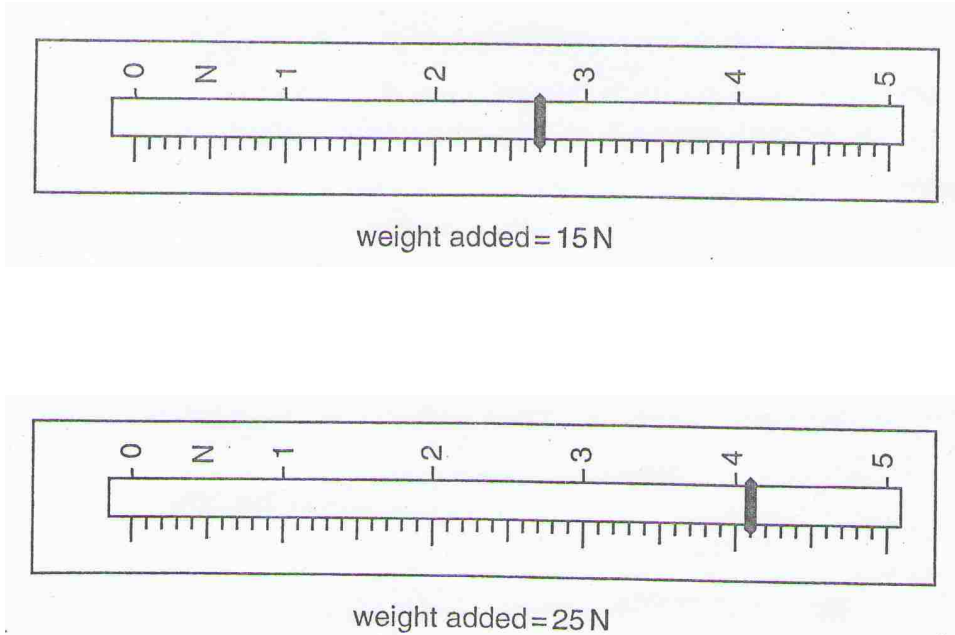


Figure 2.3

For each weight, read the scale and record the force needed in Figure 2.2
(2)

SPS

CRITERIA

.....
.....(1)

(b) On the grid, Figure 2.4, plot a graph of pulling force against weight added. Draw the best straight line to fit the points plotted.

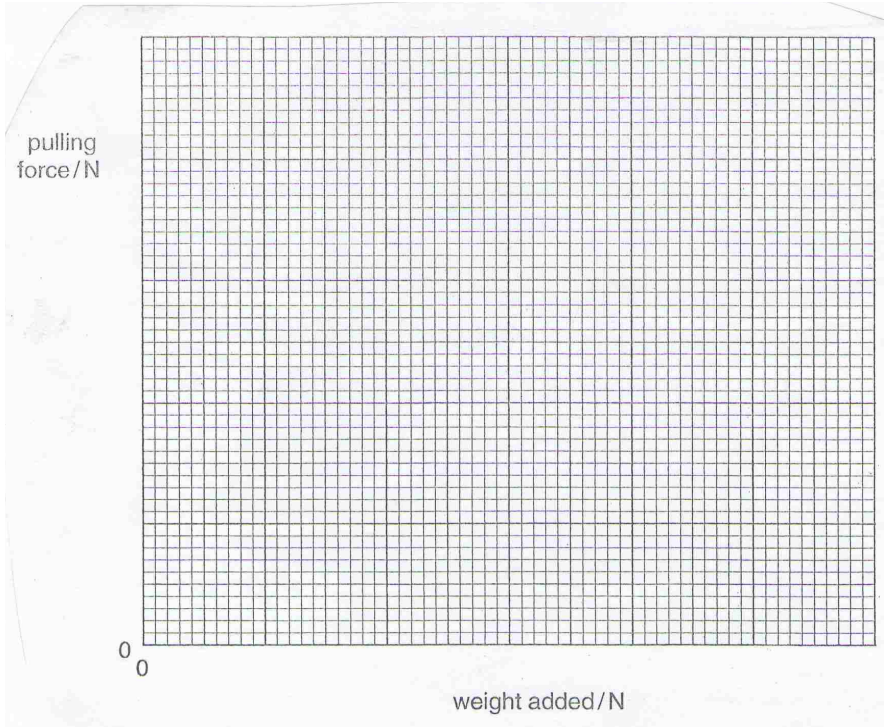


Figure 2.4

SPS

CRITERIA

.....
 (1)

(c) Describe the relationship between force and the weight.

.....(1)

SPS

CRITERIA

.....
(1)

(d) Use your graph to comment on whether the weight of the slider alone affected the results.

.....
(2)

SPS

CRITERIA

.....
(1)

(e) Calculate the slope of the line, showing **on the graph** how you do this.

.....
.....
.....
.....(3)

SPS

CRITERIA

.....
.....
.....
.....(1)

(f) It was suggested that the temperature of the slider increases as it is pulled along the surface.

Describe an experiment you could do to test this suggestion.

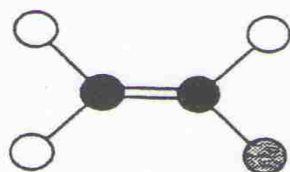
.....
.....
.....
.....
.....(4)

SPS

CRITERIA

.....
.....(1)

3. The diagram shows a molecule of vinyl chloride (used to make PVC).
(2001 paper 1 May)



key

- , a carbon atom
- , a chlorine atom
- , a hydrogen atom

What is the formula of vinyl chloride?

- A CH_2Cl_3
- B CH_3Cl_2
- C C_2HCl_3
- D $\text{C}_2\text{H}_3\text{Cl}$

(1)

SPS

CRITERIA

.....
.....
.....(1)

4. The figure below shows a beaker of water with a small amount of dye at the bottom. The beaker is then gently heated.
(2000 paper 2 November)

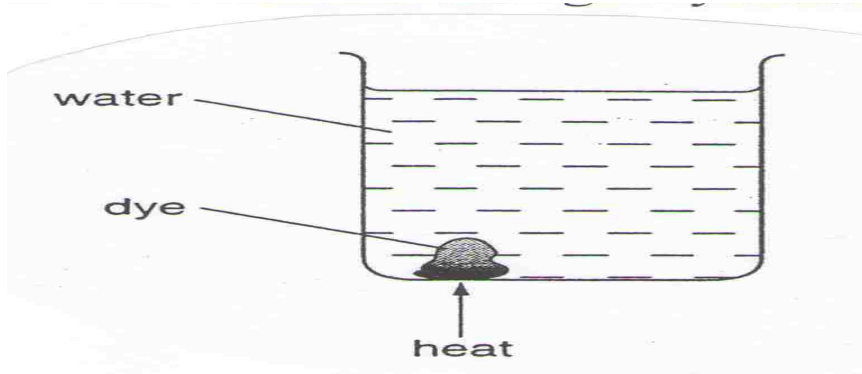


Figure 4.1

(a) (i) Describe what you would expect to see. (You may find it helpful to add to the diagram.)

.....
.....
.....(3)

SPS

CRITERIA

.....
.....(1)

(ii) Name the process which is demonstrated by this experiment.

.....(1)

SPS

CRITERIA

.....
.....(1)

(iii) Explain why this happens.

.....
.....
.....(3)

SPS

CRITERIA

.....

Appendix C

NAME: _____ YOUR LETTER: _____ DATE: _____

PHASE 3 INDIVIDUAL WORK SHEET

Instructions:

Answer all questions in the spaces provided. Under **SPS** state a science process skill you performed while writing the answer and under **CRITERIA** write evidence in the answer that confirms that the skill you have indicated is present. Temperatures are all in centigrade.

1. A student did two experiments to compare the rate of cooling of 100 cm^3 of water at 70° with the rate of cooling of 100 cm^3 of water at 40° .

(1999 paper 6 winter)

Experiment 1

- He heated 100 cm^3 of water to 75° in a glass beaker, and then poured it into a plastic cup.
- He measured the temperature of the water and, when it cooled to 70° he started the clock.
- He measured the temperature to the nearest 0.5° every minute for the next five minutes.

Experiment 2

- He heated another 100 cm^3 of water to 45° in a glass beaker, and then poured it into a plastic cup.
- He began to record the temperature every minute when the water had cooled to 40° .

- (a) The diagrams in Figure 1.1 show the thermometer scales for the readings that the student made in experiment 1

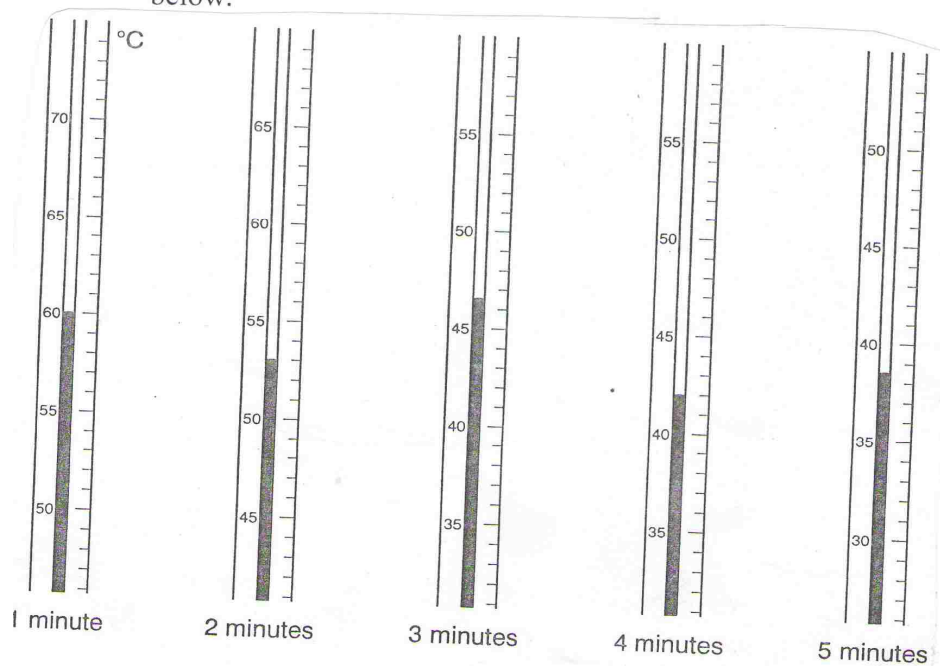


Figure 1.1

Read the thermometers and record the temperatures in the table below.

Time/min	0	1	2	3	4	5
Temperature/°C	70					

(3)

SPS

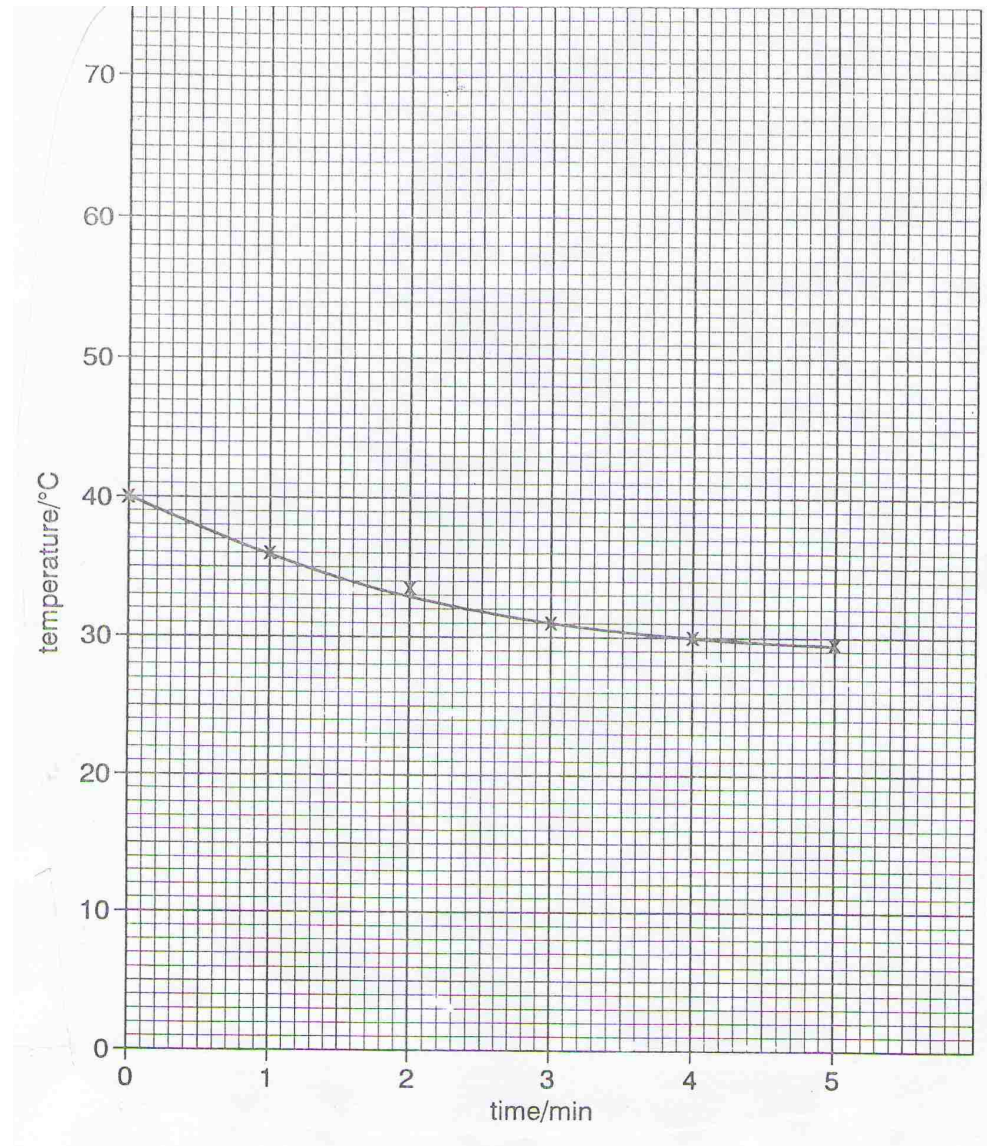
CRITERIA

.....

.....
(1)

- (b) The graph shows the student's results for Experiment 2. Plot the Results for Experiment 1 on the same axes, and draw a smooth curve through the points.

(2)



SPS

CRITERIA

- (c) (i)(1)
 Which curve, from Experiment 1 or Experiment 2, shows the greater rate of cooling during the first two minutes? Explain your answer.

.....(2)

<u>SPS</u>	<u>CRITERIA</u>	
.....	.....	(1)

(ii) Calculate the rate of cooling for the first two minutes for the curve you chose in (i).

(2)

<u>SPS</u>	<u>CRITERIA.</u>	
.....	.....	(1)

(ii) Predict the temperature at which the rate of cooling becomes zero.

..... (1)

<u>SPS</u>	<u>CRITERIA</u>	
.....	.....	(1)

(iii) Describe an experiment you could do to find out whether cotton wool could be used for keeping a cup of water cold on a hot day. Cold water and cotton wool are available together with a plastic cup, measuring cylinder and thermometer.

.....

.....

.....

.....

..... (4)

<u>SPS</u>	<u>CRITERIA</u>	
.....	
.....	.....	(1)

2. A student added 0.06g magnesium ribbon to excess hydrochloric acid. She measured the total volume of hydrogen gas produced every minute for 10 minutes. She plotted a graph of the total volume of hydrogen gas against time. The graph is shown in Figure 2.1. (2001 paper 6 November)

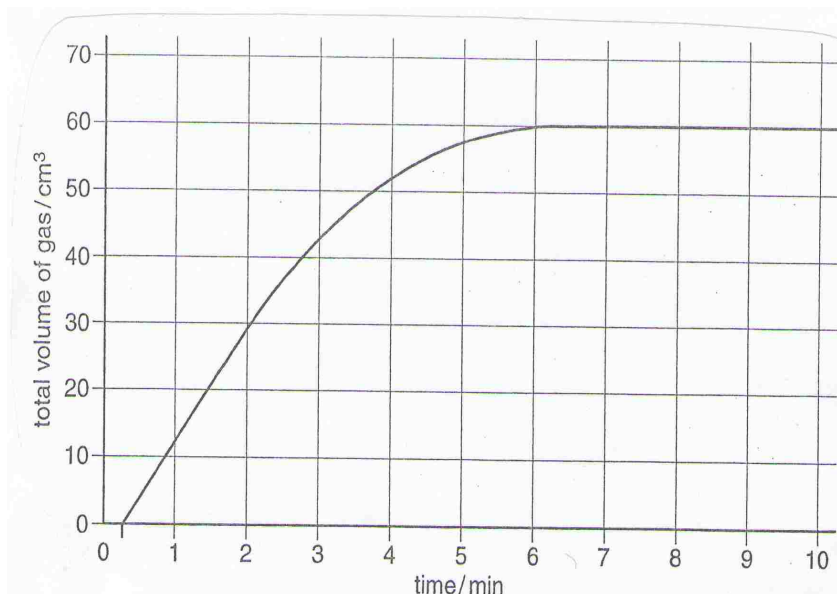


Figure 2.1

(a) Draw a diagram showing how an apparatus might have been set up by the student to react the magnesium with the acid and collect the hydrogen gas.

(3)

SPS

.....

CRITERIA

.....
(1)

- (b) The student noticed that the graph leveled out after six minutes. Explain why this happened.

.....
(2)

SPS

CRITERIA

-(1)
 (c) The student repeated the experiment using 0.03 g of magnesium with **excess** acid and plotted a new graph on the same axes.

In Figure 2.1, draw the new graph and label it **A**

SPS

CRITERIA

-(1)
 (d) The student repeated the experiment, this time using 0.06g of magnesium with **excess** acid. She first cut the magnesium into smaller pieces. She plotted another graph on the same axes. In Figure 2.1, draw this new graph and label it **B**. (2)

SPS

CRITERIA

.....(1)

3. The structures of four organic compounds are shown below.
 (2001 paper 1 November)

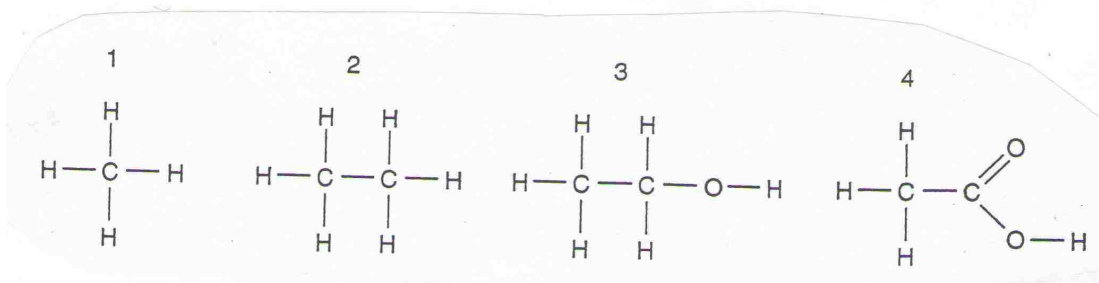


Figure 3.1

Which is correctly named? (Circle one)

	Structure	Name
A	1	Methane
B	2	ethene
C	3	Ethanoic acid
D	4	ethanol

SPS

CRITERIA

(1)

.....
.....(1)

4. A student is learning about organic chemistry. The teacher suggests that a paper clip can represent a molecule, Figure 4.1
(2001 paper 1 November)

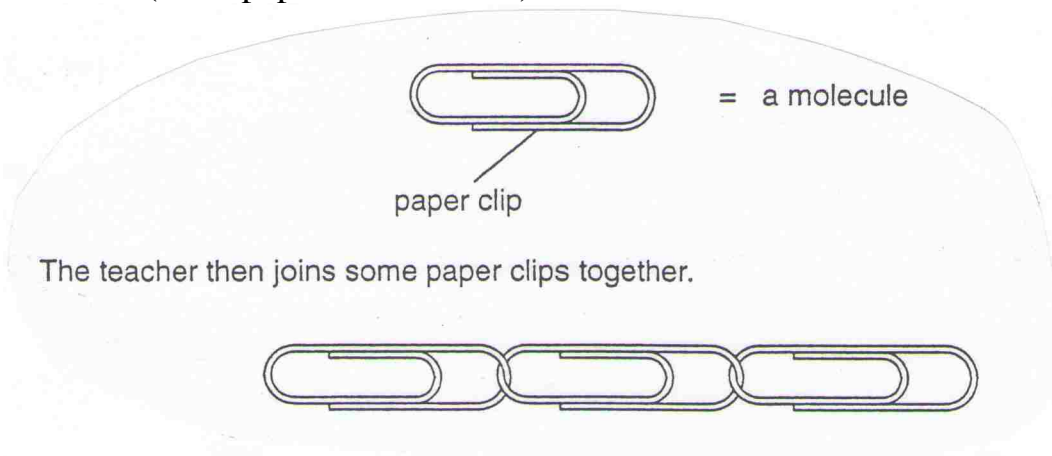


Figure 4.1

Which process is the teacher explaining? (circle one)

- A cracking
- B fermentation
- C fractional distillation
- D polymerisation

(1)

SPS

CRITERIA

.....(1)

5(a) Draw a 'dot and cross' diagram to show the arrangement of the bonding electrons in hydrogen, H_2 .
(2003 paper 6 May/June)

(2)

(b) When ethene, C_2H_4 , reacts with hydrogen in an addition reaction, an alkane is formed.

(i) Name the alkane that is formed

.....(1)

SPS CRITERIA
.....(1)

(ii) Draw the structure of this alkane.

.....(2)
SPS CRITERIA
.....(1)

(c) When ethene reacts with itself in an addition reaction, a polymer is formed.

(i) Name the polymer.
.....(1)

SPS CRITERIA
.....(1)

(ii) Draw the repeating unit of this polymer.

.....(2)
SPS CRITERIA
.....(1)

6 A student is required to find the shape of the magnetic field around a bar magnet. She is given a plotting compass and a sheet of plain paper. She places the magnet on the paper and the compass close to the magnet, as shown in Figure 6.1 (2001 paper 2 November)

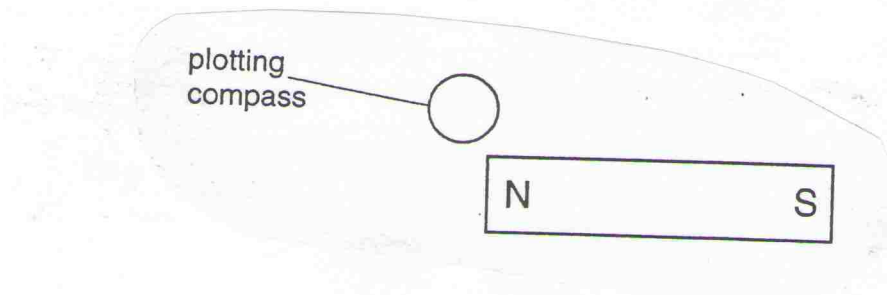


Figure 6.1

The circle represents the plotting compass.

- (a) Draw an arrow in the circle to show the direction of the pointer. (1)

SPS

CRITERIA

.....(1)

- (b) Describe how the student should proceed to plot the magnetic field.

.....(1)

SPS

CRITERIA

.....(1)

- (c) On the figure below, sketch the magnetic field shape of the magnet.

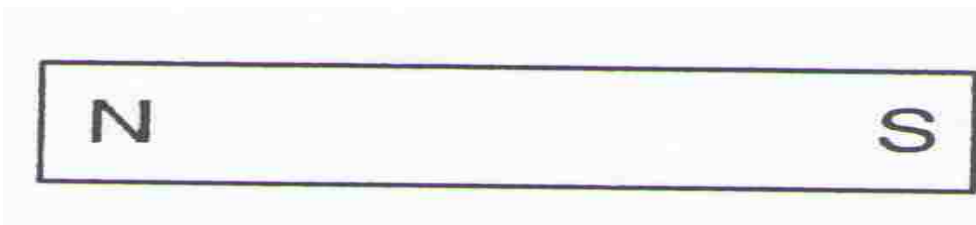


Figure 6.2

SPS

CRITERIA

(2)

.....(1)

7. (a) A student placed a crystal of potassium manganate(VII) in a test tube of water. He stood the test tube in a rack and left it there. The diagrams, Figure 7.1, show what the tube looked like after two hours and after one day.



Figure 7.1

(i) Explain what happened to the particles in the crystal.
(2)

SPS

CRITERIA

.....(1)

(ii) Suggest two ways to speed up the processes happening in the tube.

1.

2.(2)

SPS

CRITERIA

.....(1)

(b). Calcium Hydroxide is a white solid slightly soluble in water. The student placed some calcium hydroxide into a test tube with five drops of the Universal Indicator. The Universal Indicator turned purple.

What does this colour tell you about the calcium hydroxide?

.....(1)

SPS

CRITERIA

.....(1)

c).The student carefully poured some dilute ethanoic acid into the mixture from (b) and left the tube in the rack. Figure 7.2 shows what the looked like after a few hours.

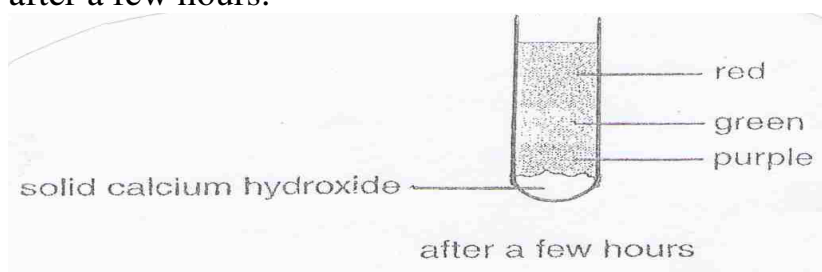


Figure 7.2

(i) Explain the meaning of the word *dilute*.
(1)

SPS

CRITERIA

.....
(1)

(ii) Explain what has happened in the green part of the solution.
(2)

SPS

CRITERIA

.....
(1)

(iii) Explain what has happened in the purple part of the solution
(1)

SPS

CRITERIA

.....
(1)