A CASE STUDY OF THE NATURE OF BIOLOGY PRACTICAL WORK IN TWO SECONDARY SCHOOLS IN NAMIBIA

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Procedural skills

Process skills

Scientific inquiry

Scaffolding

ABSTRACT

The aim of the study was to investigate the nature of biology practical work and associated discourses in two Namibian secondary schools. The purposive sample consisted of three biology teachers and 36 grade 11 students who enrolled for NSSC Higher- and Ordinary-level biology in 2004 and 2005. The study adopted a descriptive and an in-depth qualitative design involving the use of interviews and observation schedules (Video Observation Quoting Schedules-VOQS). The quality of VOQS instruments were established through a panel of independent experts who critically assessed the quality of the items and later discussed to reach consensus. Their rating of the items helped in the establishment of interrater reliability. The case study covered three interrelated questions namely:

1. What types of practical activities and related discourses are used by the three biology teachers involved in this study to facilitate the development of process skills among the students?
2. What types of instructional strategies do they use to prepare their students for practical biology examinations?
3. In what way do the teachers' views and beliefs about practical work inform their instructional practices?

The findings showed that the teachers used mainly two types of practical activities namely: group experiments and teacher demonstrations intermingled with lectures. A variety of practical activities were arranged that seemed to have a great potential to develop process skills as well as to enable students to take the NSSC Higher- and Ordinary-level biology examinations. However, teacher demonstrations appeared to focus mainly on some process skills such as making observations, recording observational results and writing conclusions while the group experiments offered more opportunities for students to exercise the intended process skills enunciated in the new Namibian biology curriculum. The students at both schools have negative views about teacher demonstrations since these did not appear to offer many opportunities to enable students to exercise process skills or to attain necessary hands-on experiences as group experiments did.

Secondly, interactive teacher interventional strategies during the intervening lectures appeared to provide more opportunities for the students to discuss or debate and negotiate subject content knowledge at the inter-mental plane compared to the authoritative interventional strategies in teacher demonstrations. Teachers who practised interactive interventional strategies seemed to pose more open-ended questions, share, shape, select, check and make key scientific ideas compared to teachers who practised close-ended and authoritative interventional strategies. As a result, teachers who used authoritative interventional strategies, with closed-ended and/or clarification questions seemed to provide limited opportunities for classroom interactions. In other words, students had fewer chances to negotiate meanings to construct new

understanding of concepts or practical skills than their counterparts who were exposed to interactive interventional strategies.

Lastly, the nature of the schools (in terms of the teachers' professional experiences, nature of the laboratories and available resources and the number of the students) seemed to create problems for teachers in deciding which appropriate teaching/learning strategies needed to be used to organize diverse practical activities. For example, schools with more resources seemed to provide students with more opportunities for attaining process skills than Schools with less poorly managed schools. Another factor that seemed to have direct impact on the way practical work was taught was the teachers' conceptions of practical work. As shown in a number of related literature, the superiority of group experiments over teacher demonstrations or vice versa depended to a large extent on a number of contextual factors (e.g. teaching/learning environment, the experience of the teacher and the availability or otherwise of resources) and no only on the teaching strategies.

However, more information is needed to determine the context in which to use a particular instructional strategy. Whatever the case, policy makers, teacher trainers and other stakeholders have an important role to play in providing the necessary resources for schools, as well as training, re-training and upgrading teachers to use instructional strategies that are most appropriate for a given instructional context. Also, there is need to conduct studies to determine how teachers' views and beliefs inform their instructional practices.

DEDICATION

This thesis is dedicated to my loving children Tangee U. Marenga and Vijandamuje Marenga, my dear husband, Sam R.P. Marenga and in memory of my late parents my mother, Lucresia Kandjeo and my father, Joel Hanavi who did not live long to witness this special day in my life.

"He said to me: 'It is done. I am the Alpha and Omega, the Beginning and the End. To him who is thirsty I will give to drink without cost from the spring of the water of life…."
(Revelation 21:6)

"Commit to the Lord whatever you do, and your plans will succeed."
(Proverbs 16:3)

DECLERATION

I declare that A Case Study of the Nature of Practical Work in School Biology in Two Secondary Schools in Namibia is my own work, that it has not been submitted before for any degree or examination in any other university, and that all resources I have used or quoted have been indicated and acknowledged by complete references.

HEDWIG UTJINGIRUA KANDJEO-MARENGA

15 May 2008

Signed: ____

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LIST OF ABBREVIATIONS AND ACCRONYMS

HIGCSE	Higher International General Certificate of Secondary Education
IGCSE	International General Certificate of Secondary Education
NSSC-H Level	Namibian Senior Secondary Certificate for Higher Level
NSSC-O Level	Namibian Senior Secondary Certificate for Ordinary Level
MEC	Ministry of Education and Culture
MBEC	Ministry of Basic Education and Culture
INSTANT	In-service training and assistance for Namibian teachers

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CHAPTER ONE
INTRODUCTION

To many students who studied science in Namibia during the colonial-apartheid era, the phrase "practical work" brings many unpleasant memories. I still remember the long hours of doing practical work-an activity that was not only boring but sometimes confusing to me. Some of us, black Namibians otherwise called African children, went into the laboratory knowing that the teacher would do some kind of demonstration to illustrate a particular science concept or confirm a theory. The general expectation from students during the colonial period was to watch, listen and memorise the outcomes of the demonstrations. The understanding of scientific concepts or theories and application of what was taught in relation to everyday life did not seem to be an important learning outcome.

In this chapter, I provide a brief historical background to the Namibian Education System that existed before and immediately after its independence from South Africa in 1990, with particular reference to science teaching. Then, I present some relevant issues concerning practical work in school biology in Namibia before considering the purpose, problem statement, significance, limitations and delimitations of the study.

1.1 Background to the study

1.1.1 Education System before Independence

Namibia (formerly called South West Africa) was a German colony from 1886 to 1915 when Germany was defeated by the Western allies (including South African forces in Namibia) in the First World War in 1915. In 1919, Namibia was mandated to South Africa as a trust territory by the League of Nations. It gained its political independence only in 1990, after a liberation struggle dating from 1966 onwards. The Namibian Education System was based on the apartheid philosophy of South Africa, which emphasised segregated development using race or skin colour to determine the type of education a student received. For the same reason the White students received better education compared to their black counterparts in relation to acquiring various life skills. The schools for white Namibian children were advantaged in many ways compared to the schools for black children and had more qualified science teachers, well equipped science laboratories and good guidance services for the students (Dahlstrom, 1995; Ottevanger, Macfarlane & Clegg, 2005). Although laboratories were part of school infrastructure in most of the schools for blacks, little was done in such laboratories for the purpose intended namely, to teach and enhance students' process skills. According to the Revised National Curriculum Statement Grades R-9 Schools Policy published by the Department of Education (DOE) of South Africa (2002):

> The term 'process skills' refers to the student's cognitive activity of creating meaning and structure from new information and experiences. Examples of process skills include observing, making measurement, classifying data, making inferences and formulating questions for investigation. The term should not be understood as referring to the manipulative skills which are a small subset of process skills…From the teaching point of view, process skills can be seen as building blocks from which suitable science tasks are constructed…From the learning point of view, process skills are an important and necessary means by which the learner engages with the world and gains intellectual control of it through the formation of concepts. (p. 13).

Ogunniyi and Mikalsen (2004) and Tobin (1994) reiterate a similar view to that of the South African DOE by regarding process skills as "intellectual tools or strategies used for performing cognitive tasks…process skills entail the use of concepts, and the manipulation of concepts involves process skills" (Ogunniyi & Mikalsen, 2004, p. 152). They argue further that process skills can only be inferred from actions (detectable for example by interviewing or observing the person concerned), such as verbal or written responses even in situations where such skills have not been deliberately taught. They also maintain that, "it cannot be assumed that there is a one-to-one correspondence between a demonstrated process skill and a singular cognitive activity in that the constituent elements of such a skill cannot be reduced to classes of experience" (Ogunniyi & Mikalsen, 2004, p. 152).

While some black schools in Namibia during the colonial era had science laboratories, others did not offer science subjects at all and, in some cases, the teachers could only carry out demonstrations to allow students to memorise science concepts. The teaching and learning approaches were teacher-centred, i.e. a sort of chalk and talk and rote- learning mode of instruction where the focus was on the teacher transmitting knowledge to the students. The majority of black Namibian science teachers (as in many African countries) were not well trained and as a result, science concepts were poorly taught to students. Hence, the type of school science to which students were exposed neither equipped them sufficiently with knowledge or skills that coincided with their intellectual interests nor was it compatible with the goals of the science curriculum (Angula, 1993; MEC, 2004; Ogunniyi, 1988, 1995, Ogunniyi & Mikalsen, 2004; Ogunniyi & Taale, 2004; Wellington, 2000).

1.1.2 The Education System after Independence

In 1990 the inherited Apartheid Education System in Namibia did not meet the aspirations of the newly independent nation nor the objectives of the Ministry of Education and Culture (Angula, 1993; Rollnick, 1998b) to make Namibia a truly politically and economically independent nation. The new Curriculum Statement of 1991 stressed student-centred activities at all levels of education, not the transmission of a host of disjointed scientific facts to be committed to memory.

The Namibian Education System at the primary and secondary school levels is designated as 4:3:3:2; that is, four years of lower primary, three years of upper primary, three years of junior secondary and two years of senior secondary school. Thus, the curriculum reform was enacted in order to educate and equip students with necessary knowledge, skills and attitudes that would enable them to meet the social demands in their respective communities (Angula, 1993; Rollnick, 1998b).

The reformed curriculum brought some major changes and these include: (i) a compulsory mathematics and science curriculum as from grades 1 to 10; (ii) the offering of science subjects in many schools across the country; (iii) a student-centred approach to teaching and learning science rather than the transmission approach; and (iv) the writing of practical examinations (Paper 3) at the end of the senior secondary level which now constitutes 19% of the total score of the final examination (NSSC H-Level Biology Syllabus, 2006). Before the science curriculum was reformed, practical work was not assessed or examined. Hence, science teachers who carried out practical work did so in whatever way they liked while others did not bother to include practical work instruction.

Practical work was not a priority in the colonial science curriculum. The focus of the science examination was the recall of scientific facts rather than presenting science as a holistic human activity which also entailed the acquisition of procedural skills and attitudes (Duggan & Gott, 2002; Ogunniyi, 1995; Ogunniyi & Mikalsen, 2004). As a result, black students were not adequately prepared for future science-related jobs nor were they able to develop necessary awareness about the values of science in their daily lives. However, their white counterparts had considerable exposure to practical work. The disparity in the awareness and understanding of the two groups of students was largely created by a segregated educational system based on race or colour (Angula, 1993; Dahlstrom, 1995; MEC, 1992; Ottevanger et al., 2005).

In Namibia, the senior secondary school curriculum is divided into two major streams: the Namibian Senior Secondary Certificate Higher Level (NSSC-H Level) and the Namibian Senior Secondary Certificate Ordinary Level (NSSC-O Level). Different schools may offer either (i) NSSC-H Level, (ii) or both NSSC-H Level and NSSC-O Level or (iii) only the NSSC-O Level syllabus. The NSSC-H and the NSSC-O subject content alternatives are comparable to the Standard

Grade and the Higher Grade curricula in South Africa, though not necessarily the same. The new science curriculum is divided into three domains. The present study focuses on Domain C, which deals specifically with practical work and biology as a part of the science curriculum. The following Figure 1 describes the intended learning outcomes for practical work.

DOMAIN C: Practical (Experimental and Investigative) Skills and Abilities

Learners should be able to:

1. Follow sequence of instructions; using appropriate techniques; handling apparatus/ materials competently and having due regard for safety;
2. Make and record estimates, observations and measurements accurately;
3. Handling and processing experimental observations and data, including dealing with anomalous or inconsistent results;
4. Apply scientific knowledge and understanding to make interpretations and to draw appropriate conclusions from practical observations and data;
5. Plan, design and carry out investigations (based on concepts familiar to learners) and suggest modifications in the light of experience.

Figure 1.1: Ministry of Education and Culture, NSSC-H Level Biology Syllabus: Conceptual and Experimental Assessment Learning Outcomes (2006, p. 32-33)

Domain C indicates the intended learning outcomes for practical work, i.e. to enable the students to develop necessary experimental and investigative skills as stipulated in the NSSC curriculum. Teachers are expected to provide necessary learning opportunities that will enable their students to acquire the intended learning outcomes (Cambridge Syndicate Higher International General Certificate Secondary Education (CSHIGCSE) Biology Syllabus, 2005; MEC, 2003; NSSC H- and/or O-level Biology Syllabus, 2006).

In view of the above stated learning outcomes for practical work, it becomes obvious that Biology teachers should adapt their teaching strategies in such a way that would enable them to achieve the intended learning outcomes. Nevertheless, good as the intention of the NSSC Biology curriculum might be, the nagging question is, “Are Biology teachers teaching in such a way that the intended learning outcomes are achieved?” In other words, are current instructional practices of Biology teachers compatible with the aims and learning outcomes of the NSSC curriculum? Is there a correspondence between theory and practice? All of these are pertinent questions warranting closer consideration.

In developing countries, practical work is rarely conducted and the traditional transmission method still prevails (Bekalo & Welford, 1999; 2000; Dahlstrom, 1995; Kapenda, Kandjeo-Marenga, !Gaoseb, Kasanda & Lubben, 2001; Tjikuua, 2001). These authors cited argue that practical work is conducted mainly in the form of demonstrations. They assert that such practices could conceivably deny the students the acquisition of practical experiences critical to the development of procedural and conceptual skills as emphasized in their science curricula. It is now more than a decade since the new curriculum was introduced into Namibian schools. But practical work, as an essential aspect of science instruction, remains a perennial problem for most of the science teachers in Namibia. It is for the same reason that some scholars have argued that teachers rarely set up practical work that enhances the development of the procedural and conceptual skills at the advanced levels of thinking (Bekalo & Welford, 2000; Duggan & Gott, 2002; Kapenda et al., 2001).

The situation described above is, of course, not peculiar to Namibia. Prophet (1990) noted that "the majority of laboratory work involved teacher-talk, using either the lecture technique or a simple question and answer routine that demanded only basic recall from the pupils, often as words or simple sentences" (p. 16). Ogunniyi (1995) and Erduran (2003) makes similar remarks with respect to the mismatch between what is presented in the science syllabus and the kinds of teaching and learning that take place in the classroom. The questions now are: (i) What kind of process skills are intended, taught and examined in the Biology syllabus in Namibia? (ii) What are the Biology teachers' views of practical work? (iii) How do Biology teachers' views and beliefs affect their practices when conducting practical work? These and similar concerns are addressed in the study. But before investigating the nature of practical work in School Biology in Namibia, it is important to clarify the concept of practical work in greater detail.

Practical work

It is crucial for any researcher exploring the nature of practical work to have a deeper understanding of what practical work is, what it entails, and what can be regarded as good practices in science education. Henry (1975) defines practical work as being "any activity involving learners in real situations, using genuine materials, and properly working equipment" (pp. 61-62). He also includes simulated experiences, pencil-and-paper exercises and fieldwork. On the other hand, Bekalo and Welford (2000), Brown (1995) and Woolnough (1994) consider practical work to involve activities such as hands-on experiments, observations, demonstrations, group discussions, interactions, simple paper-pencil class work and projects. In addition to the above definitions, Millar, Marechal and Tiberghien (1999) define practical work as being "all those teaching and learning activities in science which involve students at some point in handling or observing real objects or materials they are studying or direct representations of these, in simulation or a video-recording" (p. 36).

Practical work as defined in the literature involves more than manipulative activities. It is broad endeavour which also involves the students' active participation in the learning process skills in terms of both conceptual and procedural skills (DOE, 2002; Frost & Youens, 2005; Howe & Smith, 1998; Lubben & Millar, 1996; Ogunniyi & Mikalsen, 2004). Activities suggested in the definitions above involve students engaging in hands-on or mind-on practices (Bekalo & Welford, 2000; Frost & Youens, 2005; Keys & Kennedy, 1999; McCarthy, 2005; Roth, 1995). Furthermore, conceptual skills involve the ability to read, write, estimate, predict, and translate pictorial representations, the selection of instruments and materials accurately while procedural skills deal with the ability to use scientific methods such as observation, measurement, collection of data, and carrying out investigations (Chiappetta & Fillman, 2007; Duggan & Gott, 2002; Frost & Youens, 2005; Gott & Duggan, 1996; 2002; Roberts & Gott, 1999; Tobin, 1984).

An examination of the definitions above shows that practical work embraces a broader meaning than is often realized. It also entails demonstrations, individual or group project work as well as field trips and even computer simulated experiments (Bekalo & Welford, 2000; Brown, 1995; Millar et al., 1999; Woolnough, 1994). An exploration of the biology learning outcomes for practical work would in the new curriculum show that the suggested practical activities require the availability of human and material resources. The argument is that teachers may develop behaviour that might tempt them to make excuses not to teach a particular topic or in a particular manner (Bryan, 2003; Crawford, 2007; Liu & Chiu, 2008) and thus, jeopardise the teaching and learning of some learning outcomes meant to develop certain process skills.

Despite some problems experienced in conducting practical work in schools, Clackson and Wright (1992) observed positive outcomes in terms of critical thinking and manipulative skills among students exposed to laboratory materials and procedures compared to their counterparts who were not so exposed. They also pointed out that there are different reasons to justify the need for practical work, even though in some developing countries practical work is not a part of the science curriculum. But despite the positive findings on practical work that have been reported in the existing literature it must be conceded that such finding are by no means conclusive. Some studies have shown that practical work is useful in the development of critical process skills while others have indicated differently (Donnelly, 1998; Hodson, 1992; 1993; 1998; Hodson & Bencze, 1998; Millar & Driver, 1987).

Science teachers are seen to be the core personnel, facilitators or mentors in the education system charged with the task of assisting and providing opportunities to students to be involved in laboratory activities. They are seen as the mediators or a bridge between their students and the science fraternity (Chin, 2006; Oh, 2005; Wu & Hsieh; 2006). Some scholars (Matinez-Losanda & Garcia-Barros, 2005; Verjovsky & Waldegg, 2005) argue that it is important for teachers to know what they should explicitly focus on in teaching both the nature of science and/or process skills (experimental and investigative skills) in order to avoid confusing their students. Such knowledge is imperative for any science teacher in order to translate the intended learning outcomes into appropriate and teachable activities (Clackson & Wright, 1992; Gott & Duggan, 1996; Verjovsky & Waldegg, 2005). Furthermore, it is argued that the students need multiple forms of support and multiple learning opportunities to learn. Inconsistencies between what teachers believe and what they practise might affect the students' learning (Brown & Melaer, 2006; Puntambekar & Kolodner, 2005).

The next subsection explores science investigations as one of practical activities through which process skills could be developed.

1.2.1 Science Investigations

As indicated in the earlier sections, practical work includes different activities. In the context of school science, practical work includes inquiry activities such as investigations (Chiappetta & Fillman, 2007; Duggan & Gott, 2002; Woolnough, 2000; Wu & Hsieh, 2006). During investigations, students plan and carry out open-ended or closed activities as well as evaluate the results (Parkinson, 1994; Wu & Krajcik; 2005). There is a need for students to be encouraged to (i) plan and carry out what has been planned; (ii) find out why the plan has or has not succeeded; (iii) what they should do to improve on the procedures if the task is to be repeated in conducting investigations; and (iv) query their own conceptual understanding. These imply that science teachers as mentors and facilitators of learning should themselves be capable and competent in helping the students to carry out investigations in an effective way (Duggan & Gott, 2002; Parkinson, 1994; Puntambekar & Kolodner, 2005).

In addition, interactions and conversation during practical work play a very important role. The teacher provides (through utterances) guidance during the teaching-learning process. Classroom conversations involve utterances, which include (e.g. teacher talk, student talks) and other means of communication tools such as images and class activities (Scott & Jewitt, 2003) which combine to help students during the planning and carrying out of the practical work. The teacher and the students talk around the given activity and in so doing attempt to establish the scientific concepts about what is being learned (Driver, 1983; Mortimer & Scott, 2000; Nakhleh, Polles & Malina, 2002; Scott & Jewitt, 2003). These scholars further note that for most of the time the teacher is directing and guiding the talks during an activity and the students also may directly influence the flow of classroom discourse.

During a classroom/laboratory discourse, the teacher and the students may talk about the same thing but may approach the topic from different directions because of their different views about what is being studied. During such talks, both the teacher and the students are using socio-cultural tools such as utterances (e.g. descriptions, explanations and generalisations), social languages (e.g. scientific and everyday language), images (e.g. diagrams, drawings and images) and speech genres (e.g. everyday genre of greeting, genre of table conversation, everyday story telling, genres of classroom discourse) in order to clarify the subject under discussion (Jones, 2000; Mortimer & Scott, 2000; Nakhleh at al., 2002; Scott & Jewitt, 2003; Staver, 1998). In other words, everyday genres of classroom discourse or story telling or examples given will aid in helping the teachers to guide their students. It is argued that such assistance provides support to students in enabling them to make sense of the scientific knowledge. Mortimer and Scott (2000) further argue that speech genres are distinctive forms of utterances and that they are tied to classes of speech situation rather than to classes of speakers. The assumption here is that the students will acquire skills and understand how to work as scientists through the process of enculturation (Lewis, 2002; Lijnse, 1995; Sutton, 1998). The next subsection explores some ways and means by which process skills in practical work can be developed.

1.2.2 Process skills and investigations

As discussed in Chapter 2, one of the purposes of involving the students in practical work is to develop their process skills including critical thinking and the ability to manipulate objects or variables in the context of an investigation. Process skills, as mentioned in section 1.1.1, are a much broader concept and include procedural and conceptual skills (DOE of South Africa, 2002; Ogunniyi & Mikalsen, 2004). But before clarifying the two terminologies further, it is apposite to provide additional information about process skills as a whole.

Process skills consist of basic and integrated skills. The basic skills involve process skills such as observing, measuring, inferring, predicting, classifying, collecting and recording data, while the integrated skills are at higher level of thinking such as interpreting data, controlling variables, defining operationally and formulating hypotheses (Tobin, 1994). It is believed that the basic process skills are important for understanding and using the integrated process skills but some researchers assume that not all process skills can be taught. Some of the basic process skills are inherently learned through interactions with one's environment while others are not (DOE of South Africa, 2002; Hodson, 1996b; Martin, Sexton, Wagner & Gerlovich, 1997; Ogunniyi & Mikalsen, 2004; Tobin, 1984).

Process skills such as identifying variables, controlling variables, hypothesising, designing a fair experiment, and carrying out investigations and drawing conclusions are inter-related to the understanding of science concepts (Ogunniyi, 2003; Ogunniyi & Mikalsen, 2004). Similarly, some scholars have argued (e.g. Tobin, 1984; 1994; Wu & Krajcik, 2005) that process skills learning appears to be more successful when lessons are merged into the regular science curriculum over an extended period rather than learning it over a short period as is often done in science classes. In other words, the teaching of process skills becomes meaningful when linked to familiar contents or themes and with purposes whereas teaching process skills in a vacuum will be meaningless to students (Gott

& Duggan, 1995; Marinez-Losanda & Garcia-Barros, 2005; Martin et al., 1997). For example, a student may use cognitive skills to process information in order to select a valid test, an appropriate instrument, or the most appropriate graph (line graph or bar graph) to solve a problem. In other words, integrated process skills should include practical reasoning skills based on the use of inscriptions, which are the tools that scientists employ to solve identified problems (Duggan & Gott, 2002; Gilbert, 2003; Nakhleh et al., 2002; Vygotsky, 1978; Wu & Krajcik, 2005).

Conceptual/cognitive processes are involved in understanding substantive concepts and procedural ideas (Gott & Mashiter, 1991; Roberts & Gott, 1999; 2000). Cognitive processes are manipulated in one's mind, first in thought and then overtly by language or by action and are referred to as 'thinking behind the doing' or 'the knowing how' (Roberts & Gott, 1999, p. 20). For example, one may ask himself/herself as to why the step he/she took in solving a particular problem was wrong. This question depicts a conceptual skill that can facilitate the steps to problem solving. One needs to give evidence based on substantive scientific concepts and theories to undertake the step-by-step procedure involved in problem solving (Gott & Duggan, 1995; Hodson, 1996b; Tobin, 1984). Central to the idea of procedural understanding is that the students be involved in guided investigative work to enhance their development of process skills (Duggan & Gott, 2002). Hodson (1996b) summarises this broadly by asserting that:

> Learning science is not simply a matter of making sense of the world in whatever terms and for whatever reasons to satisfy the learner. Learning science involves an introduction into the world of concepts, ideas, understandings and theories that scientists have developed and accumulated. It is an attempt to explain and account for the real nature of the physical universe, regardless of whether it makes sense in the everyday meaning of that explanation (p. 127).

Hodson's (1990; 1996b) view above is a clear indication of why the students encounter difficulties in science. Science, to a degree, is counter-intuitive while the students' worldviews are largely intuitive and commonsensical. To disregard this reality is to alienate students from school science. Hence, when teachers attempt to explain and describe the scientific worldview and/or the nature of science to students, they need not only be aware and recognise the students' traditional cultural views but also at the same time they act as cultural brokers for successful enculturation to take place (Aikenhead & Jegede, 1999; Brown-Acquay, 2003; Jegede, Fraser & Okebukola, 1994; Qhobela, Rollnick, & Stanton, 2003). Although western science is the dominant one in the world, both indigenous and western science should be taught in school science in non-western societies (Cobern, 1996; Ogawa, 1993). Cobern (1996) further argues that children keep their indigenous science and are never free from it. Ogunniyi, Jegede, Ogawa, Yandila and Oladele, (1995) consider this notion when referring to a culturally sensitive science curriculum within a non-western scientific context. Based on Ogunniyi's notions of harmonious dualism and contiguity hypotheses (1988; 1995) or his current stance on the Contiguity Argumentation Theory (Ogunniyi, 2007a & b) and Aikenhead and Jegede's (1999) theories of collateral learning and cultural border crossing, it seems that students in a biology class must face the challenge of resolving their cognitive conflicts to relate their real life situations with canonical school biology. It is also important to note that science curricula that seem to embrace students in constructivist discussions of socio-cultural views about science concepts alter students' attitudes toward teaching of science (Jegede et al., 1994).

According to the theories mentioned above, the students' everyday experiences are distinctly different from what they are exposed to in a science class. Thus, practical work could provide an excellent opportunity for students to resolve their cognitive conflicts. As students observe phenomena, discuss and reflect on their new experiences, they are in a better position to deconstruct and re-construct their worldviews (Cobern, 1996; De Vries, Lund & Baker, 2002) in the light of their new experiences than if they have simply been informed when conducting practical work (Qhobela et al., 2003).

According to Warwick, Stephenson and Webster, (2003) there is a need to allow students to communicate to others in writing. The argument here is that most students found it easier to express their thinking (e.g. procedural understanding) verbally rather than in writing. The students seem to use the spoken language easily to express their thoughts about procedural skills such as giving reasons to why they selected this testing procedure and not another, identifying concepts associated with measurement and data handling, identifying concepts associated with experimental design rather than putting these ideas on paper.

Lastly, process skills are applied when students need to follow procedures. Gott and Duggan (1995, p. 14) refer to these practical skills "as the mechanics of the use of measuring instruments and how to construct a graph". For the purpose of the present study, only those process skills namely experimental and investigative skills/conceptual depicted in the NSSC-H Level Biology syllabus considered. The next subsection describes the theoretical frame work that underpins the present study.

1.3 Theoretical framework

The study is underpinned by personal and socio-cultural constructivist theories of learning as espoused in the works of Piaget, Vygotsky, von Glaserfeld and Driver. In general, the constructivist theories of learning deal with how students develop conceptual and procedural knowledge through experiences. The theories of learning also provide teachers with useful information about how students learn (Broth, 1993; Driver, 1983; Jenkins, 2001; Matthews, 1994; Piaget, 1952; 1964). For example, teachers consult the theories of learning when they select instructional strategies in order to create conducive opportunities for teaching and learning environments.

The personal and socio-cultural constructivist learning theories have one focus in common, that is, students are considered to be actively engaged in what they learn (Chin, 2007; Jenkins, 2001; Kittleson & Southerland, 2004). According to Jenkins

(2001) a student or an individual does not acquire knowledge passively. Rather he/she acquires knowledge by constructing new knowledge through his/her personal or social interactions with the subject content (Acar & Tarhan, 2007; Chin, 2007). Piaget (1964) argues that the learning process is an adaptive and dynamic process. He refers to this process of adaptation as equilibration. He further asserts that the acquisition of new knowledge by children continuously enables them to adapt better to their environment. Piaget (1964) asserts that:

> To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed (p. 176).

There is, therefore, a general consensus among constructivists that students do not always receive information as given but rather they actively attempt to modify it in the way it makes sense to them. In other words, they are fully aware and are reasoning about what they are learning. Learning is, then, seen as a personal process (Acar & Tarhan, 2007; Chin, 2007; Driver, 1983; Piaget, 1952; 1964). Following from the argument that students are active participants in a learning environment, the learning environment, then, becomes an important arena where the teacher and the students meet and become engaged in the process of transmitting or acquiring new knowledge. Both the teacher and students are actively involved in the process of teaching and learning, that is, the teacher selects the best available teaching strategies in order to create a conducive learning environment in which students will participate actively in what they are learning while the students make themselves ready to act, to modify and transform new knowledge in order to internalise it (Acar & Tarhan, 2007; Chin, 2007; Jenkins, 2001; Kittleson & Southerland, 2004).

In the course of its development from personal constructivism of the Piagetian era, social constructivism has evolved into a learning theory whereby the individual is seen not as entity standing alone but as a microcosm of society, and hence the focus on learning at a social level. As social beings, students construct knowledge personally as well as socially through their interactions with peers or an expert. Learning, then, becomes a social process where knowledge construction is not perceived to be merely resting on the shoulders of the individual student alone but it is also co-constructed through social interactions involving the process of internalisation where adults, in this case teachers, provide guidance to help the students to understand the new information better (Chin, 2007; Havu-Nuutinen, 2005; Jenkins, 2001; Kittleson & Southerland, 2004; Vygotsky, 1978).

As said earlier, students are social beings and construct knowledge both individually and socially (Chin, 2007; Jenkins, 2001; Kittleson & Southerland, 2004; Leach & Scott, 2000). According to Vygotsky (1978) children learn cognitive and communicative tools and skills of their culture through social interactions, that is, the interpersonal processes become an intrapersonal one in the learning process. The students are not actually learning how to use these tools from scratch but are introduced into these socio-cultural heritages through social interactions – a sort of induction into the resources of their society. He further views learning to be a social process where language and dialogue play important roles in mediating cognitive development. In other words, Vygotsky's theory of constructivism gives adults, including teachers, a central role to lead students to new levels of conceptual understandings by interacting and talking with them.

The above discussion brings us to what Vygotsky (1978) called the Zone of Proximal Development (ZPD). ZPD refers to the "distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or collaboration with a more capable peer" (p. 86). The more capable person is modelling or providing guidance when it is needed or creating opportunities for children to use and take control of socio-cultural resources within their specific society. In other words, when students work alongside a teacher, his/her ZPD accelerates faster than when they are learning on their own or in the absence of an expert (Chin, 2006; Crawford, 1999; Flick, 2000; Wu &

Hsieh, 2006). Thus, learning becomes more intense in the presence of an expert (Jenkins, 2001).

When considering these learning theories, instructions, then, are seen as two-way activities where the teacher and the students collaborate in the acquisition of new knowledge. Both the teacher and the students are actively involved during the process of instruction and learning in order to narrow the gap between what is already known and what is to be learned, that is, the potential developmental level and the actual developmental level. In addition, Roth (1995) sees science laboratory and classrooms as construction sites. From a constructivist perspective, teachers expect their students to be actively engaged in practical tasks through interactions. Although students are expected to use the cookbook recipes, they are provided with opportunities to exercise practical skills with the assistance of an expert namely, the science teacher (Chin, 2006; Davis & Sumara, 2002; Liang & Gabel, 2005; Morge, 2005; Oh, 2005).

From a social constructivist view, learning in a group or alongside an expert is seen to have an advantage because it offers the room for a discourse situation, whereby meanings could be negotiated at a social level (De Vries et al., 2002; Leach & Scott, 2000; Roth, 1995). As an expert, the teacher intervenes to develop and be available scientific matters and skills to all the students in the classroom by shaping, selecting, marking, sharing, checking and reviewing students' ideas at the social level (Chin, 2006; Liang & Gabel, 2005; Morge, 2005; Mortimer & Scott, 2003; Oh, 2005). The present study embraces this form of inquiry and focuses on classroom discourses that take place in the biology classrooms/laboratories in the process of tackling a given task.

Despite its strengths and its contributions to learning in general, Staver (1998, pp. 501-502) has levelled the following criticisms against constructivism. For example, constructivism:

- Is considered to be a flawed instrumental epistemology.
- Tends towards relativism.
- Fails to break away from the traditional empiricist view of science.
- Does not accurately portray the practice of science

According to Bennett (2003), Tobin and Tippins (1993) and Taylor (1998) constructivism as a learning theory cannot be used as a model for teaching but simply as a referent. So far, constructivism does not give a clear guide to bring about change in students' alternative conceptions. Matthews (1994) and Broth (1993) argue that there are persistent issues that science teachers are faced with during instruction in constructivist classrooms. For example, (i) What should the science teacher do when a student constructs different meaning from the one intended by the teacher? (ii) What teaching techniques are unique to constructivism? (iii) How should the curriculum be seen? (iv) Should it be construed as a body of knowledge and skills or as a programme of activities from which knowledge and skills could possibly be acquired or constructed? These and related questions are not easy to answer because there are many answers to each question. It is not clear from a constructivist viewpoint what the teacher ought to do when faced with issues raised by these questions (Jenkins, 2001). In social constructivism, however, there is room for the teacher to mentor, negotiate and model in order to provide internship or mediate learning (Havu-Nuutinen, 2005).

Jenkins (2001) argues that constructivism does not offer support to teachers on how they should provide guidance during instruction to their students. It does not seem to offer much on what is the best and most effective way to engage students in classroom activities. He contends, for example, that constructivist learning does not provide a clear description of: (i) what it is that science teachers want their students to construct; (ii) what it is that science teachers are supposed to do in order to enable the students to construct new knowledge; and (iii) whether classroom activities and practices can be justified in terms of the time and resources associated with them.

Despite the criticisms that have been levelled against constructivism, there is no doubt that this theoretical construct currently exerts a significant impact on science curriculum development and instructional practices in many countries around the world. Viewed in this way, the classroom is seen as a multi-social setting that has implications for the teaching/learning process (Broth, 1993; Gwimbi, 2003). The classroom/laboratory setting needs to take an account of the purposes and meanings constructed by the students. The present study is only concerned with exploring the guidance provided by the teacher as a facilitator, guide and mentor in a constructivist classroom. The teacher, as mentor, negotiates and interprets the social knowledge in collaboration with his/her students in order to enable them to transform the social knowledge into personal knowledge (inter-mental and intra-mental) (Chin, 2007; Jenkins, 2001; Kittleson & Southerland, 2004). The nature of the discourse that evolves during practical work or demonstration is important because it provides some insight into the type or quality of interactions going on in that social setting.

1.4 Statement of the problem

My experience in teaching Biology for eight years at the senior secondary school level as well as being a teacher-educator (for 10 years) has exposed me to the type of problems commonly encountered in the teaching of Biology. The most frequently encountered problems by Biology teachers include: (i) the inability of teachers to conduct inquiry activities; (ii) individual teaching difficulties in providing opportunities for practical experiences; (iii) the lack of resources; and (iv) the lack of skills in supporting the students when conducting inquiry work (Angula, 1993; Onwu, 1998; Rollnick, 1998b).

On the other hand, most students do not seem to be able to: (1) devise an experiment; (2) follow simple instructions; (3) carry out simple mathematical calculations; (3) plot and read information from or interpret graphs and tables; (4) demonstrate adequate observation skills; (5) exhibit good drawing skills; (6) use scientific knowledge and understanding; and (7) use comparative language

(Cambridge Local Examination Syndicate Biology, 1998; 2004; 2005). These problems among others have motivated me to conduct the present study.

1.5 Purpose of the study

Explored in the present study, was the nature of instructional practices and how such practices impacted the way practical work in biology was carried out in two Namibian schools. Further, the study attempted to find out whether or not the nature of instructional practices and how concomitant discourses enhance the development of essential practical skills in biology among the students. More specifically, the study was aimed at determining:

1. The types of practical activities and related discourses used by Namibian Biology teachers to facilitate the development of process skills among their students.
2. The types of instructional strategies the Namibian Biology teachers used to prepare their students for the practical examinations.
3. The teachers' views and beliefs about practical work and how such views and beliefs inform their instructional practices in the Biology laboratory/classroom.

1.6 Research Questions

In pursuance of the above aims, answers were sought to the following questions:

1. What types of practical activities and related discourses are used by Namibian Biology teachers to facilitate the development of process skills among their students?
2. What types of instructional strategies are used by Namibian Biology teachers to prepare their students for practical examination?
3. What are the Biology teachers' views of and beliefs about practical work and how do such views and beliefs inform their instructional practices in the Biology laboratory/ classroom?

1.7 Significance of the study

The significance of the study is to provide a deeper insight into the nature of classroom/ laboratory interactions in biology as well as make biology teachers aware of their practices and shortcomings when designing and conducting practical activities. Similarly, it is hoped that teachers' advisers, curriculum developers and policy-makers might become aware of the feasibility or otherwise of practical work and/or practical examinations in biology in Namibian schools. Furthermore, it is hoped that findings from the study would provide useful information for teacher trainers in their attempt to equip prospective and practising teachers with the necessary knowledge and skills to implement the new curriculum which now makes practical work compulsory for all Namibian secondary schools. As indicated earlier, practical examination amounts to 19% of the final School Certificate examination in Namibia. Since the final School Certificate Examination maintains a stranglehold effect on the education system in Namibia, it can be expected that the outcomes of the study would receive the necessary attention of a range of stakeholders other than the teachers.

1.8 Limitations of the study

The study explored issues in relation to the types of practical activities and the types of instructional strategies used by three volunteer biology teachers in the Windhoek Educational Region. The discussions of the identified limitations of the study are integrated with appropriate section 2.2.5 and sections 3.2.1.1 and 3.2.2.2 and 3.5 in Chapter 2 and Chapter 3 respectively.

1.9 Operational definitions of terms key terms

For ease of reference, I have provided the operational definitions for a number of key concepts used in the study. The purpose here is to contextualize what these key terms mean in the present study.

Practical work

- Practical work is generally defined as all "those teaching and learning activities in science which involve students at some point in handling or observing real objects or materials they study or direct representations of these, in simulation or a video-recording" (Millar et al., 1999, p. 36). An easy way to describe this is to relate practical work to what students do both physically and mentally; i.e. minds-on and hands-on activities (Bekalo & Welford, 2000; Henry, 1975; Woolnough, 1994). The students learn practical and investigative skills by being involved in various practical tasks.
- Practical work involves activities such as hands-on experiments, observations, demonstrations, group discussions, simple paper-pencil class work, projects, exercises and fieldwork (Bekalo & Welford, 2000; Brown, 1995; Woolnough, 1994). The students are involved in handling materials and manipulating equipment, follow procedures, selecting appropriate ways to present experimental and observation results and to some extent select appropriate plans to carry out investigations as well as to use a variety of practical skills in order to complete these practical tasks under the close supervision of the teacher (MEC, Biology syllabus, 2006).

Practical skills

- Practical skills are process skills that are acquired while performing a scientific investigation such as setting up, reading and using instruments, constructing a line graph, using the thermometer or reading measurements (DOE of South Africa, 2002; Gott & Duggan, 1995; 1996; Ogunniyi & Mikalsen, 2004).

Scientific Inquiry

- Scientific inquiry is generally defined as a process of asking questions, generating data through systematic observation or experimentation, interpreting data and drawing conclusions (Sandoval & Reiser, 2004).
- The students are expected to have knowledge of the kind of questions that

can be answered through inquiry, the kind of methods that are accepted within disciplines for generating data and standards for what counts as legitimate interpretations of data (Hofstein, Novon, Kipmis, & Mamlo-Naaman, 2005; Wu & Hsieh, 2006; Wu & Krajcik, 2005).

- In the classroom scientific inquiry consists of "making observations, posing questions, examining books and other sources of information, planning investigations, reviewing what is already known in light of evidence, using tools to gather, analyse and interpret data, proposing answers, explanations and predictions and communicating results" (Roehrig & Luft, 2004, p. 3).

Process skills

- Process skills are regarded as those ways of thinking, measuring, solving problems and pursuing thoughts in science education. Process skills are tools that scientists use to understand and unravel the physical environment in which they live (Wu & Hsieh, 2006; Wu & Krajcik, 2005).
- Process skills are classified as procedural skills and conceptual skills. Procedural skills involve the understanding and application of skills and concepts of evidence such as the concept of the fair test, identification of variables as independent and dependent, validity and reliability (Gott & Duggan, 1995). These involve the evidence of valid conceptions of science concepts, ability to apply scientific concepts and skills innovatively, the use of scientific knowledge and skills in making rational decisions, the ability to distinguish between scientific and alternative conceptions of natural phenomena and an awareness to revise conceptions in the face of new scientific information (Ogunniyi & Mikalsen, 2004).
- Conceptual skills in this study are regarded as those skills which students use in high level thinking and are associated with any intellectual activity including the solving of scientific problems such as observing, classifying and inferring (Gott & Duggan, 1995; Martin et al., 1997).

Practical activities

- These are activities which are planned to engage students in a scientific inquiry or an investigation under the close supervision of the teacher (Bekalo & Welford, 2000; McCarthy, 2005; Millar et al., 1999).
- These include activities such as demonstrations, class experiments (all on similar task), a circus of experiments (small groups on different activities), simulations and role-play, investigations and problem-solving activities (Roberts & Gott, 1999; Wellington, 1994).

Teaching strategies

- Teaching strategies are based on learning theories. These are techniques, sequence and methods used by teachers to enhance learning. It also involves multitudes of responsibilities given to the teacher during instruction (Brooks & Brooks, 1993; Richardson, 1997; Watt, Jofili, & Bezerra, 1997).
- These strategies are techniques that present information to the students in a manner that promotes learning such as exercises, demonstrations, tutorials, projects and producing biological models. A teacher may provide a variety of sensory experiences in the form of learning activities (Richardson, 1997; Scaife, 2000; Staver, 1998).

Classroom interactions

- Interactions and conversation play a very important role. The teacher provides guidance through what is called utterances during interactions. In such a conversation, the utterances involve e.g. teacher talk, student talk, and other means of communication tools help students during the planning and carrying out of the investigations (Chin, 2007; Scott & Jewitt, 2003; Warwick, Linfield, & Stephenson, 1999).
- The teacher and students talk around the given activity and in so doing they establish meaning about what is to be learned (Chin, 2006; Driver, 1983; Kittleson & Southerland, 2004; Mortimer & Scott, 2000).

Constructivism

- Constructivist epistemology construes learning as the construction of knowledge by an individual and tries to explain a set of beliefs on how individuals learn in terms of the context they live in (Havu-Nuutinen, 2005; Liang & Gabel, 2005; Matthews, 1994; Oh, 2005; Staver, 1998).
- Constructivism is a learning theory and a teaching referent. In this regard the science laboratory or classroom is a construction site (Roth, 1995). From a constructivist perspective, students are expected to be actively and socially engaged in what they are learning during practical tasks (Leach & Scott, 2000; Liang & Gabel, 2005; Oh, 2005).

Social constructivism

- Social constructivism is concerned with the acquisition of knowledge through social interactions. Learning is seen as personal and social and is communicated through socially constructed tools such as language, semiotics and other teaching and learning tools that are used to distribute scientific knowledge (Liang & Gabel, 2005; Oh, 2005; Shepardson & Britch, 2006; Tobin et al., 1990; Vygotsky, 1978).
- In a socio-constructivist classroom, the teacher's role is changed to that of a facilitator to provide opportunities where students are able to mediate and construct meaning of what they are learning (Liang & Gabel, 2005; Maor & Taylor, 1995; Morge, 2005; Oh, 2005).

Apprenticeship

- Apprenticeship is defined as a process through which individuals become members of a certain community by internalising knowledge and skills as practised in that community. It is believed that new individuals pick up relevant social language by imitating behaviours of skilled members and gradually start to behave in accordance with the community's norms and values (Hodson & Hodson, 1998b).
- This involves a teaching strategy that starts at a level where the more knowledgeable person namely, the coach, guides and supports the less

knowledgeable person, i.e. the students. They then imitate the behaviours of the teacher and in so doing gain practical skills and the know-how to conduct investigations (Chin, 2007; Kittleson & Southerland, 2004).

Scaffolding

- It is seen as a purposeful act on the part of the teacher or the more knowledgeable person in assisting the less knowledgeable person (Hodson & Hodson, 1998b; Holton & Clarke, 2006; Liang & Gabel, 2005; Oh, 2005; Shepardson & Britch, 2006).
- Scaffolding is an act of teaching that supports the immediate construction of knowledge by the student and provides the basis for the future independent learning of the student (Gregory, 2002; Hodson & Clarke, 2006). Acts of scaffolding can be posing questions that may stimulate further thinking (Liang & Gabel, 2005; Oh, 2005; Puntambekar & Kolodner, 2005).

1.10 Summary

In this chapter the researcher introduced the readers to the background of the study. The background of the study, the research problem, the research questions, theoretical framework and the significance of the study as well as the operational definition of the terms were highlighted. The next chapter will focus on the related literature conducted in the field of science education.

CHAPTER TWO

REVIEWED OF RELATED LITERATURE

2.1 Introduction

This chapter reviews the latest literature dealing with the role of practical work in school science in the context of scientific inquiry. The issues considered in this regard sketch the theoretical conceptualisation of the study with reference to recent debates. The discussion focuses on: (i) the theoretical framework as proposed by constructivists such as Piaget, and Vygotsky; (ii) the nature of science as related to practical inquiry; (iii) scientific inquiry as a form of practical work; (iv) and studies on practical inquiry in general.

2.2 Theoretical Framework

One of the most important steps in any research endeavour is to find an appropriate theoretical framework or context in which to situate the study. A theoretical framework provides the focus for the study as well as helps the researcher from pursuing shadows rather than reality (Adams, 2003; Schurink, 1998a). In order to provide a research framework for the study, a number of theories of learning that have a bearing on the teaching and learning of science were consulted. Among these, constructivism as espoused by Piaget and Vygotsky seemed most relevant to my study because it deals specifically with how students learn new experiences in a social situation. In this regard, a brief review of the contributions made by Piaget and Vygotsky who are believed to have laid down the groundwork for constructivism in the 20th century is presented in the section that follows.

2.2.1 Constructivism

Constructivism has its origin as a response to issues that dominated the science curriculum reforms during the 1960s and 1970s. It was based on the cognitive development stage model, an epistemology that is based on naïve empiricism (Brooks & Brooks, 1993; Driver, 1988; Glasersfeld, von, 1989; Osborne, 1996). Constructivism is considered to be a post-epistemological learning theory in the sense that it does not condone the traditional theories of knowledge that see knowledge as representing a real world that exists separately and independently of the knower.

To Matthews (1994) constructivism originated from two major traditions: psychological and sociological. Psychological constructivism has its roots in Piaget's descriptive theory of cognitive development while sociological constructivist originated from the scientific knowledge that is socially constructed and vindicated (Liang & Gabel, 2005; Matthews, 1994; Vygotsky, 1978) while the theory of cognitive development emphasises the individual psychological state of mind (Liang & Gabel, 2005; Oh, 2005; von Glasersfeld, 1989). Psychological constructivism gives rise to two other perspectives: radical constructivism and social constructivism. However, Jenkins (2001) has argued that all facets of constructivism as a learning theory have one major commitment, that is, the students are actively engaged in what they are learning in order to develop understanding. In other words, as Matthews (1994) puts it: "knowledge cannot be given or handed over and received in the same way as a parent might give a child a book, a toy or a tool" (p. 155). Rather, learning and the knowledge that evolves in the process of learning is an active intellectual process which involves deconstructing and constructing reality based on experience.

The conceptual framework that underpins this study has its origin in the constructivist learning theory. The constructivist epistemology construes learning as the construction of knowledge by the individuals when sensory data give meaning in relation to the individual's prior knowledge (Hewson & Hewson, 1983; 1988; Martin et al., 1997; Tobin, Rennie & Frazer, 1990). They claim that learning involves personal constructions of knowledge and, therefore, should be seen as an interpretive process by an individual (Oh, 2005). Tobin et al., (1990) argued that constructivism ought not to be considered as an option that the teachers and students can call upon during the teaching and learning situation but as a theory that can influence their classroom practices. It can influence what happened in the classroom, how activities are planned and implemented during instruction. According to Tobin et al. (1990) learning science in the constructivist sense implies "direct experience with science as a process of knowledge generation in which prior knowledge is elaborated and changed on the basis of fresh meanings negotiated with peers and the teacher" (p. 3).

There are different constructivist perspectives and the most well known are: personal, social, socio-cultural, radical and critical (Aikenhead & Jegede, 1999; Cobern, 1996; Ogunniyi, 1995; Staver, 1998; Vygotsky, 1978; Windschitl, 1999). Constructivism is a learning theory that explains a set of beliefs about how an individual learns. Staver (1998) has argued that constructivist theory attempts to explain human behaviour in terms of the context in which humans live. Humans use senses to depict what individuals experience when in their immediate environment. Human beings observe and experience how different objects behave in nature and as such, observations form a part of their basic experiences. In addition, observations provide humans with information about the external world (Staver, 1998). As a learning theory, constructivist is based on the following two principles:

1. During the learning process, individuals actively construct new knowledge and use their existing understanding in order to make sense of new situations (Matthews, 1994; Naylor & Keogh, 1999)
2. The learning process is an active process through which an individual constructs viable explanations of his/her experiences (Wheatley, 1991).

The main features of constructivist perspective of learning are summarized in the following way:

1. The learning environment and the knowledge of the students influence the learning outcomes.
2. Learning involves the construction of meanings. Meaning construction by individuals from what they see or hear may or may not be those intended and in turn, this may be influenced to a large extent by any existing knowledge.
3. The construction of meanings is an active process.
4. Once meaning is constructed, it is evaluated and can be accepted or rejected.
5. Individuals have a final responsibility for their own learning.
6. There are patterns in the types of meanings individuals construct owing to shared experiences with the physical world and through natural language. (Bennett, 2003; Driver, 1988; Matthews, 1994).

The constructivist perspective among other perspectives contributes to the value of teaching and learning in science education. The main contributions are listed below:

1. Epistemological issues are moved into the foreground in the discussions about learning and curriculum (Osborne, 1996; Phillips, 1995).
2. Empirical data is provided in order to enhance our knowledge of the difficulties in learning science (Osborne, 1996).
3. Development of innovative methods of science teaching is fostered (Matthews, 1992; Osborne, 1996; 1997).
4. Teachers' awareness of the students is increased (Osborne, 1996).

Most of the science educators consider the constructivist view to be a powerful model because it provides some information on how to promote conceptual change in students (Jenkins, 2001; Naylor & Keogh, 1999).

According to Millar and Driver (1987), students do not enter the classroom with empty minds. They hold a multiplicity of worldviews derived from their common experiences as they interact with their physical and social environments. Millar and Driver (1987) argue that when students encounter new information, they make use of their existing knowledge to understand the new information or situation. They also maintain that the students bring to the classroom prior sets of ideas and internal mental representations to any interaction with the environment. Learning, thus, is viewed as a change in the cognitive structures of an individual when the individual interacts with the environment and constructs viable explanations about his or her experiences (Millar & Driver, 1987; Wickman & Ostman, 2002).

The students are seen as individuals who can actively construct meanings through their mental processes. The mental structures or processes of the individual are enhanced by engagement with new content or with others during social interactions (Millar & Driver, 1987; Naylor & Keogh, 1999; Taylor, 1998). In other words, the conceptual understanding of a student is actively constructed and reconstructed on a continuous basis through debating and negotiating meanings with one another as well as with teachers and peers (Benze, 2000; Crawford, 1999; Flick, 2000; Jenkins, 2001; Maor & Taylor, 1995). Windschitl (1999) points out that:

> Constructivism is premised on the proposition that learners actively create and restructure knowledge in highly individual ways, basing these fluid intellectual configurations on their formal instruction experiences, bits and pieces of personal theory, social and cultural contexts in which ideas occur, and a host of other influences that serves to mediate understanding (p. 190).

The immediate environment of the students mentioned in this regard is seen to influence the learning process. The environment of the students in this case will include the following aspects: (a) personal theories (derived from their own experiences as they interact with objects and others); (b) their cultures;

(c) social values and norms (gained from their communities); and (d) instruction (informal or formal instruction). Formal instruction involves the interactions with scientific knowledge, in particular, the practical skills and abilities (Tobin, 1995; Windschitl, 1999).

Some educators refer to constructivism as a referent whereby the teacher is seen to support a set of constructivist teaching behaviours in their classrooms. It is seen as a set of beliefs concerned with knowledge and knowing and as such can be used to inform classroom activities that would maximise situations for learning to take place (Brooks & Brooks, 1993; Davis & Sumara, 2002; Richardson, 1997; Tobin, 1995; Tobin & Tippins, 1993). The teacher simply supports those classroom situations and learning activities that maximise the students' learning (Tobin et al., 1990). According to Tobin et al (1990) and Tobin (1995), the teacher provides the necessary sensory experiences and increases the social interactions among the students in order to enable them to negotiate meanings. Tobin argues that in order to improve learning, the teacher should know how to improve the quality of some essential components of the classroom context such as the social process, making sense, experience and the students' existing knowledge. His view is based on planning and implementing strategies that focus on the needs of the students as seen from the constructivist view. Tobin (1995) argues that

> The teachers' role is to monitor student understandings and guide discussions so that students have opportunities to put language to their understandings and to engage in activities such as clarifying, elaborating, justifying and evaluating alternative points of view. Such visions of classroom learning environment are exciting and appeal as viable alternatives to those so often reported in studies of learning in traditional classrooms (p. 302).

In some cases, the constructivist theory is applied as an instructional model. Constructivism is a learning theory and cannot be used as a model for teaching but simply as a referent (Bennett, 2003; Taylor, 1998; Tobin & Tippins, 1993). So far, constructivism does not have clear suggestions to bring about change in the students' alternative conceptions. Constructivism becomes very difficult to explain due to its various forms that differ from one another so much but in some certain areas still overlap. Some forms focus on the cognitive structure of an individual (Havu-Nuutinen, 2005; von Glasersfeld, 1989), Piaget (1964) focuses on how individuals learn, while Vygotsky (1978) concentrates on social constructivism. One common characteristic among the constructivist perspectives lies in a commitment to the idea that learning is an active process and it requires the students to be actively engaged in what they are learning (Driver, 1983; Martin et al., 1997; Millar & Driver, 1987; Piaget, 1952; von Glasersfeld, 1989; Vygotsky, 1978). According to Jenkins (2001) knowledge does not simply jump from the environment into the mind of an individual but much needs to be done by the teacher to enable students to learn scientific knowledge as practised within the scientific community. Jenkins (2001) argues that the learning process is complex and should not be seen as a straightforward process. He also argues that

> The notion of the mind actively constructing knowledge does not, for example, lead in any logical way to a rejection of the world as an external reality. Nor does it require the problematic idea that science education is about 'making sense' of the world rather than about establishing a valid scientific understanding of natural phenomena (p. 155).

Jenkins (2001) asserts further that some progressivist claims such as children are natural scientists (Driver, 1983) are misleading from the viewpoint of science education. A teaching theory is more complex than a learning theory. For example, it should accommodate a range of aspects, which are not included in the theory of learning. He further emphasizes that constructivism does not offer modest support to teachers on how they should provide guidance during instruction to their students. It does not seem to offer much on what is the best and most effective way to engage the students in classroom activities as mentioned earlier in chapter 1.

Phillips (1995) on the other hand, argues that some educators and researchers consider constructivism as a "powerful folktale about the origins of human knowledge. As in all religions, constructivism has many sects – each of which harbours some distrust of its rivals" (p. 1). Despite the good points that are emphasised by various researchers, it also has positive and negative parts. Phillips' (1995) view about the negative points on constructivism is

> the tendency within many forms of constructivist epistemology (despite occasional protestations to the contrary) towards relativism, or towards treating the justification of our knowledge as being entirely a matter of socio-political processes or consensus, or toward the jetting of any substantial rational justification or warrant at all (as is arguably the case with the radical constructivists) (p. 11 - 12).

Phillips (1995) has argued that issues surrounding epistemology have become the centre of most current academic writing and debates on learning and the curriculum are due to discussions on constructivism as a progressive learning theory. His view is that these controversies have arisen from the claims of constructivism to be a progressivist learning theory. He assumes that any justifiable epistemology should recognise the fact that nature exerts considerable restrictions over our knowledge-constructing activities and it allows us to detect and/or reject our errors about it. The views expressed above on learning as an active engagement of the mind and the importance of expert scientific knowledge on the part of the teacher have implications for classroom practices in science education (Broth, 1993; Gwimbi, 2003; Osborne & Collins, 2001) in relation to practical work in school science and are addressed in the following sections.

2.2.2 Personal constructivist perspective

The personal constructivist perspective emphasises that learning is an individual process and that knowledge is constructed through the experience of senses (Scaife, 2000). In other words, knowledge construction and intellectual development are considered from an individual's point of view but not from a social point of view. This view is related to Piaget's cognitive development as a foundation of the conservative constructivist's perspectives (Martin et al., 1997). Piaget's work has contributed significantly to modern constructivist epistemology.

Although not the originator of the word "schema", namely the cognitive framework for learning or interpretation of experience, Piaget (1978) has articulated the idea clearly enough for instrumental purposes. To him, a schema represents the cognitive structure through which a student organizes his/her perception of the environment into a meaningful system of descriptions and explanations. The view of Martin et al. (1997) is that as the student interacts with his/her environment, s/he learns to adapt to that environment by modifying his/her schemas (schemata) that are used to create a good match between an already acquired view of reality and that of the environment. In the process, she/he organizes or interprets his/her schemata into higher-order cognitive systems that are used. By accommodation, Piaget (1952) means that expansion or elaboration of schemas (schemata) by providing more room for the new idea, which does not yet fit the old idea. By assimilation, he means the incorporation of new ideas into the existing schemata, which ultimately results in a form of equilibrium, i.e. a dynamic mental state in which there is a balance between assimilation and accommodation. He has called this process equilibration (Coony, Cross, & Trunk, 1993; Driver, 1983; McNally, 1973; Ogunniyi, 1986; Piaget, 1952; Windschitl, 1999).

Piaget's work provided a foundation for other theorists who are associated with cognitive development. This theory attempts to describe how individuals learn through interactions with their environment. Piaget (1952) considers knowledge attainment to be a personal and individual process, that is, the students are seen as active individuals who are actively engaged in reconstructing their existing knowledge by restructuring their mental structures (cognitive structures). He asserts that an individual constructs knowledge when she/he interacts with people and objects in the immediate environment through the senses. He further asserts that the process takes place through the process of assimilation and accommodation as described in the previous chapter. In other words, interactions with one's environment tend to result in a change in his/her cognitive structure (Driver, 1983; Scaife, 2002). This change is necessary to accommodate the new experiences. According to Piaget (1952), the change in cognitive structures takes place in sequential and developmental phases or stages, namely:

- Sensory stage (0-2 years) – newborn babies up to the age of approximately two years old, when the child starts to crawl, fall in this period. Infants are most of the time non-verbal but do take a lot of information through their senses. Children start to associate with other members of the family and language starts to develop. First, the infants start to make sounds, then words, and then later on during development they start to form sentences.
- Pre-operational stage (2-7 years) – the age range from approximately two to seven years. During this stage, children become more comfortable with language. They start with formal education at pre-primary school levels. They are unable to reverse their thinking and tend to be more intuitive, egocentric and irrational as well as illogical in their thinking. In addition, they have difficulties in realizing the difference in quantities and volumes of substances and they cannot distinguish clearly between play and reality.
- Concrete stage (7-11 years) - the age range from approximately seven to eleven years. They start with formal education at primary school. Most of the children at this stage have lost their egocentric behaviour as result of their social interactions with others. Children at this stage interact with real objects but not with abstract ideas in a comfortable way. Children's thoughts become more rational and logical in their thinking and they can reverse their thought in a meaningful way when working with concrete objects. They slowly start to process events concretely and this may pave the way for the development of abilities at higher levels of thinking. They develop some ability to engage in the 'if-then' hypothetical thinking.
- Formal operational stage (11 years and onwards) - this is the last stage and takes place during early adolescence. Language is very much developed and they use it to manoeuvre their thoughts. They start to think more formally and in an abstract manner and they also start to focus on their careers. They are also able to consider many alternatives in order to solve a problem (Coony et al., 1993; Driver, 1983; Martin et al., 1997; Piaget, 1952).

However, not many individuals reach this formal operational stage. Some stagnate at the concrete stage, their abilities never develop into high order thinking abilities, and the majority of children do not develop formal operations until later in secondary school (Driver, 1983). According to Piaget's theory of cognitive development, the reasoning skills of the students are believed to advance as they grow physically. This sequential development of the students in terms of age has not always been found to conform to Piaget's stage theory. For instance, Ogunniyi (2003) carried out a study on a heterogeneous group of grade seven and nine students in South African secondary schools on the issue of scientific processing skills on gases. The aim was to gain an understanding of the students' conceptions of various scientific concepts not only in terms of right or wrong responses but also in terms of specific process skills they used in performing certain cognitive tasks. The findings showed that the 12 - 17 year old students seemed not to have advanced in their reasoning in relation to scientific process skills. In most of the research tests the 13 - 14 year olds performed better than the 16 – 17 year olds – i.e. a reverse of the Piagetian stage theory.

Shayer and Adey (1992a; 1992b; 1993), and Shayer (1999) explored the acceleration of the development of formal thinking of the students in British middle and high schools and they used the Piagetian tests in order to test the students' achievement in Science, Mathematics and English. The intervention programme was intended to promote formal operational thinking in students between 11 or 12 years of age and then at 16 years of age. The findings showed that the experimental group showed better science achievement of greater magnitude. The 12 year olds showed higher achievement in Mathematics. Shayer and Adey (1992a; 1992b; 1993) affirm that the differences in the formal operational thinking could be attributed to factors such as: (i) the intervention method which could have favoured abstract analytical learning instead of concrete objects; (ii) increase in the general intellectual capacity that takes place during these years in adolescence and (iii) the methodology which was specifically designed to increase meta-cognitive development of the students.

Westbrook and Marek (1992) investigated the students' understanding of the concept of homeostasis. They engaged grade seven Life Science students, grade ten Biology students and the college students who were enrolled for the Zoology course. The aim of the study was to explore the misconceptions that the students had in relation to homeostasis. Each student was asked to respond to a test consisting of a biographical questionnaire, two Piagetian-like developmental tasks and a concept evaluation statement. The findings support the idea that the students at the concrete operational stage seemed to have difficulties in learning formal concepts. The students in the formal operational stage also showed less and an incomplete understanding of the concept of homeostasis and the misconceptions seemed to persist in the students of all ages. All the above studies show the difficulty and complexity of the context involved in investigating and interpreting formal operational thinking processes in individuals.

Piaget's contribution to instruction in science can be summarised as follows:

- Knowledge should be constructed actively and not just dictated or transmitted to students (Coony et al., 1993; Driver, 1983).
- Rote learning should be de-emphasized in favour if conceptualization i.e. deriving or constructing from experience (Driver, 1983).
- The students at the concrete operational stage (as most upper primary and lower secondary school students) learn best if concrete referents are used (Coony et al., 1993).
- The teaching-learning process must be leaner-centred with the teacher acting as an organizer and not a transmitter of knowledge (Driver, 1983).
- There should be a shift from teacher authority to students' responsibility for their own learning (Driver, Asoko, Leach, Mortimer & Scott, 1994).
- There is the need to tap the students' natural curiosity in the teaching-learning process (Driver, 1993; Driver et al., 1994).
- Individual differences must be given due recognition in a teaching-learning setting (Driver et al., 1994).

Despite the important aspects of Piaget's development to the instructional process, the theory exhibits the following weaknesses:

- The role of language in learning is underestimated.
- The teacher is seen more as an organizer than an active facilitator or cultural broker.
- Less emphasis is placed on the socio-cultural aspects of learning.
- The cognitive domain is over-emphasized at the expense of the affective domain.
- The individual student is seen as the creator of knowledge as if his/her knowledge evolves from a socio-cultural vacuum.

In view of the above, the present study is only concerned with examining Piaget's constructivist idea, which associates learning as an active construction of meanings as one interacts with one's environment, not whether students in a particular age range are operating actively or formally. Also, some aspects of language and logico-mathematical operations discussed by Piaget (1952) are referred to now and then in this study, because the subjects of the study are probably operating in both the concrete or formal operational stages. There is a plethora of studies indicating that both children and adults move back and forth from concrete to formal stages depending on the nature of the tasks, the process skills called for or the knowledge background of the student (Ausubel, Novak, & Hanesian, 1968).

2.2.3 Social Constructivism

The social constructivist's view espoused by Vygotsky was derived from Piaget's theory of cognitive development. Vygotsky (1978) extended the notion of intellectual development as a personal experience and personal knowledge to include social constructs where language plays a vital role (Scaife, 2000). Vygotsky is seen as the father of social constructivist theory. His work has contributed considerably to the teaching and learning of Science Education. To him, social constructivism is concerned with the acquisition of knowledge through social interactions. In the social constructivist perspective, learning is both personal and social. Vygotsky's (1978) view is that learning is communicated through socially constructed tools such as language in collaboration with others. He asserts that individuals use the socially constructed tools in conversations in terms of predetermined concepts and accepted practices to create and judge knowledge through the collective process (Erickson, 2000; Hodson & Hodson, 1998a; 1998b; Scaife, 2002; Vygotsky, 1978).

Vygotsky's notion of education is that of enculturation. In other words, learning and teaching become a process through which the teacher, an expert in the field, provides new experiences and introduces his/her students to the new ways of acquiring knowledge, new ways of arguing and new ways of communicating within the community (Vygotsky, 1978). Knowledge construction, then, does not merely rest on the shoulders of the individual child alone but it is co-constructed through social interactions involving the process of internalisation where adults, in this case teachers, provide guidance to help the child understand the new information better. As social beings, the students construct knowledge both individually and from social interactions with peers or the adult person. Vygotsky (1978) refers to the processes of internalisation as a process through which external operations are reconstructed internally. He identifies a series of transformations within the process of internalisation as involving:

- An operation that initially represents an external activity is reconstructed and begins to occur internally.
- An interpersonal process is transformed into an intrapersonal one.
- The transformation of interpersonal process into an intrapersonal one is the result of a long series of developmental events.

Vygotsky (1978) asserts that children learn cognitive and communicative tools and skills of their culture through social interactions, that is, where interpersonal processes become an intrapersonal one. He argued that through social interactions, the non-knowledgeable person is inducted into the resources of the society.

Vygotsky believed that knowledge is transmitted through history by means of mental sharing. By this notion, he meant that mental sharing is possible when ideas are passed from more knowledgeable to less able individuals. Human beings use language as a communication tool. Meaning-making when using language depends on the context in which rules are established locally in the community of scientists or other experts (Roth, 1995; Staver, 1998). Vygotsky (1978) views learning to be profoundly a social process where language and dialogue play very important roles in mediating cognitive development or act as a vehicle for understanding scientific concepts (De Vries et al., 2002). In other words, Vygotsky's theory of constructivism gives adults, including teachers as experts in the field, a central role by leading the students to new levels of conceptual understandings as they talk with them. This notion leads us to what Vygotsky (1978) calls "Zone of Proximal Development" (ZPD). The ZPD refers to the "distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or collaboration with more capable peers" (Vygotsky, 1978, p. 86). In other words, when students work alongside an expert, their (ZPD) accelerates faster than when they are learning on their own. The actual development level is determined by an individual's ability to solve problems under the guidance of a more capable person or peer (Howe, 1996; Richardson, 1997; Vadeboncoeur, 1997; Vygotsky, 1978). During teaching/ learning interactions, the teacher directs guides and encourages the students' activities to internalise external knowledge. Thus, in children, learning becomes more intense in the presence of an expert adult and/or a capable peer (Crawford, 1999; Flick, 2000; Jenkins, 2001). When students interact with a teacher or peers, their everyday concepts are transformed and internalised into a familiar and coherent system of new concepts. That is, internalisation takes place from the social plane to the intrapersonal plane.

Vygotsky (1978) expanded the notion of tools to include not only language but also laboratory instruments, semiotics and other teaching and learning tools that are used to distribute scientific knowledge (Nakhleh et al., 2002). Vygotsky

(1978) argues that socially constructed tools have distributed knowledge. For example, tools in the laboratory such as instruments are considered to carry scientific knowledge within their very design and these tools may help the students to acquire scientific knowledge only when the knowledge is evident to students. He asserts that the interactions are important within the teaching-learning environment. Social interactions are used in order to make the scientific knowledge within these tools obvious to students.

Nakhleh et al. (2002) argue that unnoticeable information/knowledge within these tools will not help the students to construct new knowledge when using these tools. In other words, such tools become a sort of a 'black box' (p. 83). They consider knowledge to arise from interactions of people, objects, places and things and therefore, knowledge needs to be seen as being distributed across people, objects, places and things in a certain context. The social context is viewed as a tool in the construction and appropriation of knowledge. In a social context, language is used as a tool in meaning making.

Staver (1998) asserts that the focus of studies within the social constructivist perspective is on the language and the group. According to him the focus of social constructivist theory seems to be two-fold: firstly, language is considered as an important component in the study of meaning making; and secondly, knowledge is created and legitimized through social interchange in many forms. He argues that language is the means through which humans communicate. Meaning making through language is based on the following three essential points:

1. social interdependence is the conduit through which we attain meaning in language;
2. within language ,meaning is dependent on the context of the social interdependence; and
3. the function served by language is primarily communal and it is paramount in continuing relationships among individuals in communities (Staver, 1998, p. 504).

According to Roth (1995) social constructivist theory directs our attention not only to an individual who tries to make meaning of his/her experiences but to an individual who is becoming a functioning member of the community before he/she internalises information at a personal level. Vygotsky (1978) expresses the above notion as a process of internalisation that consists of a series of transformations. He describes these series of transformations as follows:

1. an operation that initially represents an external activity is reconstructed and begins to occur internally.
2. an interpersonal process is transformed into an intrapersonal one. Every function in the child's cultural development appears twice: first, on the social plane level and later, on the individual level; first, between people (interpsychological), then inside the child (intrapsychological).
3. the transformation of interpersonal process into an intrapersonal one is the result of a long series of developmental events (pp. 56-57).

Roth (1995) states that in social constructivism, "robust understanding and knowledge are socially constructed through collaborative talk and interaction in and around meaningful, whole activities" (p. 17). In other words, novices develop cognitive skills by taking part in socially and culturally organised activities alongside knowledgeable others in order to become fully-fledged members of that community.

In a pedagogic situation, teaching and learning take place in a social milieu through the medium of language, be it written or spoken. It is through such a medium that the teacher and the students are in a dialogue in order to debate and negotiate what need to be learnt (Hodson & Hodson, 1998a; Richardson, 1997). This is what Vygotsky (1978) refers to as the process of internalizing the social knowledge, that is, "knowledge moves from the inter-mental plane to the intra-mental plane, from social to psychological" (Vadeboncoeur, 1997, p. 27). The individual is born into a rich social and cultural environment with objects that have particular meaning. In order for the individual to acquire this meaning embedded in objects, the individual interacts with others and so learns from them how to use these objects. In other words, the individual gains information from others in the social setting and so learning is socially mediated (Maor & Taylor, 1995). For example, the use of scientific language and concepts has a social component because these are social constructions. This transformation is thought of as taking place within the zone of proximal development (Vygotsky, 1978). The students' potentials are enhanced when students with low potential are working alongside an expert, in this case a teacher or a scientist.

Vygotsky contributed significantly to instruction in science education and his contributions can be summarised as follows:

1. Knowledge is believed to be socially constructed through collaborative talk and interactions. Therefore, focus in constructivism is on the interaction between knowledgeable person and the student (Roth, 1993a; 1993; Tobin & Tippins, 1993; Wheatley, 1991).
2. As a functioning member of society, individuals learn how to use social tools (Vygotsky, 1978).
3. Knowledge is believed to be transformed from social plane (social knowledge) to an internal plane (individual knowledge) and this takes place in the ZPD (Vygotsky, 1978).
4. The teacher is seen not as a transmitter of knowledge but as mentor; someone who provides guidance during classroom interactions (Tobin & Tippins, 1993; Wheatley, 1991).
5. Language becomes an important communication social tool through which the less able individuals are enculturated in the social knowledge when using such language in appropriation activities (Hodson & Hodson, 1998a; Vygotsky, 1978).
6. During the process of meaning making, new ideas may be accepted or rejected. Learning is, thus, not passive but purposive and individuals do control their own learning (Driver, 1988; Scaife, 2000; Vygotsky, 1978).

Vygotsky's theory of social constructivism also has its weaknesses. Since social constructivism is derived from constructivism, the former inherited some of its weaknesses from the latter. More specifically, it exhibits the following weaknesses:

1. Social constructivism, like any other type of constructivist theory, cannot be used as a teaching model but only as a referent in order to utilize the learning potential of any situation (Tobin & Tippins, 1993).
2. Students who construct their own understanding of the world are not necessarily constructing scientific knowledge (Davis & Sumara, 2002; Hodson & Hodson, 1998a).

In my view, practical work provides the necessary opportunity for the students to participate in a scientific social endeavour in which the teacher plays a guidance and supportive role. Another way to express this is that practical work enables students to acquire knowledge and skills in various ways with the assistance of an expert science teacher. As active participants, the students acquire new knowledge by using societal tools, personal meaning making and by talking to other knowledgeable individuals in their immediate environment. What Piaget and Vygotsky's cognitive theories suggest is that learning or the development of knowledge on any subject matter is both a personal and a social activity. Although learning is ultimately idiosyncratic, the learning context is often social in nature. There are times when an individual acquires a new understanding about a phenomenon on his/her own, and there are times when the individual requires this through the assistance of others. Hence, it might be safe to say that learning, particularly acquiring process skills is effectively achieved by mobilizing experiences gained by self-discovery or by interacting with members of the society in which one grows.

A survey conducted by Kerr (1963) as well as the study conducted by Swain, Monk and Johnson (1999) Hegarty-Hazel (1990) and Tamir (1990) on aims of practical work identified a set of 20 aims for school science practical work. Although there are some changes in the focus of the school science practical work over time and as seen in different countries, practical work has remained a prominent feature of the school science curriculum of many countries. Despite some changes emphasised on the nature of practical work, four major aims of school science practical work remained unchanged. The most popular aims for practical work, which are central to the nature of scientific activity, include the following: (1) the development of the scientific processes, (2) the development of scientific attitudes in the students, (3) the problem-solving approach, and (4) the development of cognitive abilities in students (Klainin, 1988; Leach & Paulsen, 1999; Millar, 1989; Millar et al., 1999; Wellington, 1994; 2000).

The set of aims as described by various researchers (Kerr, 1963; Swain et al., 1999; Tamir, 1991; Wellington, 1994) so far include aims on the affective, cognitive and psychomotor domain, that is, the aims range from scientific attitudes, scientific content (cognitive) to various motor skills (practical skills). Jenkins (1999) argues that practical work is burdened with responsibilities that it sometimes cannot realistically meet and as a result

> some of these aims are expressed in a form that is simply not testable and when this is not the case, the aims are all too often corruptions of what are really assessment objectives or, to put the matter perhaps more charitably, the outcomes of attempts to reduce practical work to what is measurable. The consequences of this, …, is the reduction of practical work to a set of techniques or allegedly distinct skills and a consequent frustration of its education potential (Jenkins, 1999, p. 26).

Perhaps, that practical work is over-burdened with responsibilities that sometimes cannot be realized, is observed in the ways the teachers arrange practical activities as well as in the purposes teachers have for involving their students in practical work. Hodson (1993) concluded that practical work, as currently arranged, overloads students with information. The students often are unable to perceive the "learning signal" (p. 100) easily. In addition, many times mismatches do occur between the teacher's intended purposes and the aims for such practical activities as well as with what the students think the teacher wants to teach (Bekalo & Welford, 2000; Erduran, 2003; Hart, Mulhall, Berry, Loughran & Gunstone, 2000). It is, however, interesting to note that those aims as identified by Kerr are still relevant today.

Many researchers debate the issue surrounding the role of practical work in school science (Donnelly, 1998; Jenkins, 1999; Kerr, 1963; Millar et al., 1999; Ntombela, 1999; Wellington, 1994; Woolnough & Allsop, 1985). The focus of such debates is the effectiveness of practical work, the scientific content needed by the students that will enable them to carry out meaningful practical work, the methods of science that need to be developed and the teachers and students' authenticity when involved in practical activities (Hodson, 1993; Millar et al., 1999; Novak, 1969). Millar et al. (1999) highlight some of the issues that are related to the ineffectiveness of practical work in school science. They considered the following set of issues as some of the outcomes of "ill-conceived, confused and unproductive" (p. 34) practices of school science practical work:

1. The students often fail to learn from the intended objectives for practical work.
2. The practical work itself is carried out very rapidly and does not provide enough time for students to learn what it is intended for them to learn.
3. Unreliable equipment is used or even in some countries there is a lack of laboratory equipment.
4. Sometimes conclusions that seem to be apparent for the teacher are not that obvious to students.
5. In most cases, the students fail to produce the phenomena, patterns, trends and explanations which they were observing.
6. The classes are mostly over-crowded in many developing countries and this makes it difficult for the teacher to provide individual attention when needed the most.

7. The assessment system used is often promoting conceptual knowledge rather than practical skills and abilities. (Millar et al., 1999)

Klainin (1988) identifies some problems of practical work in school science as experienced by the teachers and students in both developed and developing countries. The problems associated with curriculum implementation, change of emphasis in school curriculum, and problems of incentives and the problems that are associated with goals that could be attained by practical work. The problems associated with curriculum implementation include the lack of equipment, enough time (Jenkins, 2000) for practical work, safety precautions in the laboratory, and students' participation while those associated with incentives include the value of practical work held by students, teachers and curriculum developers, and the lack of reward for the students (Klainin, 1988; Wellington 1994; 2000).

Practical work is not conducted without problems as some educators may think. Practical work, as currently practised, does not seem to develop students' abilities to the extent intended. Therefore, Hodson (1991; 1992) argues that practical work is not meaningfully taught in schools and that the students' practical work is inevitably inaccurate. In science education, the nature of laboratory work is linked to various aspects of learning such as learning science, learning about science and doing science and as such brings confusion among educators and teachers. This is what Hodson (1998) refers to as "ill-defined" and "unproductive" practices of practical work in school science (p. 143). Hodson (1993) discusses at length some of the problems that the teachers, students and researchers may encounter in relation to practical work. His contributions to some of the problems as faced by teachers, students and researchers can be summarised as follows:

1. Many teachers are not well-trained to teach scientific inquiry.

2. There is a tendency for teachers and other educators to lump all inquiry activities together under the name of practical work whether practical exercise, demonstrations or investigations.

3. In some cases the rhetoric of teachers is not that indicative of their classroom

activities. There is a significant mismatch between their intended and their actual practices in the classroom (Gwimbi, 2003).

4. The teachers' teaching styles also have a significant role during practical work. Some teachers stress the teacher-centred problem-solving approach, others practise the student-centred inquiry approach whiles others favour fact finding and facts acquiring.

5. Practical work is lengthy and is often fleeting (short-lived) when one looks at the amount of time it provides conceptual learning.

6. Many times students fail to link what they are doing in practical work to what they are learning. (Hodson, 1993).

Hodson (1993) further argues that the students are put in positions where they have to understand:

> … the nature of the problem and the experimental procedure (neither of which they have been consulted about), assembled the relevant theoretical perspective (with only minimum assistance from the teacher), read, comprehend and follow the experimental directions, handle apparatus, collect the data, recognize the difference between results, write an account of the experiment (often in a curiously obscure and impersonal language), and all the time ensure that they get along reasonably well with their partners (p. 100).

The situation that is presented in the proceeding paragraph illustrates that there are too many obstructions that restrain the students from doing laboratory work in an effective way. This study attempts to look at the complex teaching-learning practices involved in practical work instruction in Biology education. More specifically, it attempts to investigate the nature of the discourse that takes place in inquiry teaching in secondary schools in Namibia. The study draws inspiration from the constructivist pedagogy in the sense that knowledge is personally constructed as well as socially mediated (Cowie, 2005; Davydov, 1995; Tobin, 1995).). The emphasis of the present study is focused on how these theories of learning provide a frame of reference for the teaching/learning practices of practical work in Biology education.

Viewed in this way, the classroom or the science laboratory is seen as a multi-social setting that has implications for the teaching and learning process. The setting needs to take an account of the purposes and meanings constructed by the various participants. The present study is only concerned with investigating the guidance provided by the teachers as a facilitators, guiders and mentors in a constructivist classroom/ laboratory. The teacher, as mentor, negotiates and interprets the social knowledge in collaboration with his/her students in order to enable them to transform that social knowledge into personal knowledge (inter-mental and intra-mental). The nature of the classroom/ laboratory discourse as one of the important aspects is investigated during practical work in Biology education.

2.2.4 Piaget's Cognitive Theory versus Social Constructivism

Piaget's cognitive theory focuses on individuals, isolated minds that construct knowledge from experiences in the world (Piaget, 1952). Roth (1995) considers this theory of knowing and learning as individualistic and inappropriate in accounting for many learning situations. The following are the main critiques made about Piaget's theory of cognitive development:

- Piaget's theory focuses on cognition and the individual (Roth, 1995).
- Piaget's theory is developmental in orientation and does not say much about teaching (O'Loughlin, 1992).
- Piaget's theory does not focus on classroom learning processes that are inherently constrained by socio-cultural and contextual factors but focused on the general principles of human reasoning (Davydov, 1995; O'Loughlin, 1992).
- Piaget concentrates more on peer interactions than the interaction between an adult and the child (Christie, 2002; Ramorogo, 1998).
- Piaget's theory remains unclear about cognitive development in instances where overt conflict and cognitive apprenticeship are depicted (Ramorogo,

1998).

- The role of language as a mediating factor during the internalisation of knowledge and the role of semiotic mechanisms that mediate learning are not given prominence in Piaget's theory (Ramorogo, 1998).

Social constructivism, on the other hand, considers individual cognitive development to be a subject of a communication between nature, history, biology and culture, the lone intellect and society (Davydov, 1995; Roth, 1995). In other words, Vygotsky's theory considers the growth of the individual mental structures as a part of the process of societal change. The following are the main features of Vygotsky's theory of social constructivism:

- Vygotsky's theory emphasises the importance of social interactions in enhancing cognitive development (Davydov, 1995).
- Vygotsky's theory stresses the role of the language (scientific) and semiotic mechanisms as a mediating factor during the internalisation of knowledge (Davydov, 1995; Hodson & Hodson, 1998b).
- The role of the teacher has changed from being the transmitter of knowledge to that of enhancing the enculturation of the students into the subculture of science. This is called "autonomous acculturation" (Hodson & Hodson, 1998a; Taylor & Cobern, 1998, p. 205).
- Vygotsky's theory does not concentrate on situational and contextual factors that consider learning (Ramorogo, 1998; Taylor & Cobern, 1998).

2.2.5 Constructivist perspective in the teaching and learning of science

As described earlier, the present study embraces the constructivist perspective of teaching and learning where a teacher and his/her students are engaged in discursive interactions. The students are seen as active participants and both the teacher and the students should be involved in discussions to negotiate meaning from what has been taught. The Namibian education system invites teachers to teach in a student-centred manner. The problem is that much of the teaching done in Namibian schools and as exemplified by the teachers involved in this study (see chapter 4) do not reflect this current emphasis on student-centredness. Both the teachers and students use teacher-centred methods as instructional approaches. Teachers prefer teaching in the traditional chalk and talk approach to cover the syllabus rather than engaging their students in classroom discourses (Kapenda et al., 2001; Tjikuua, 2001).

2.3 Scientific language during practical work instruction

The significance of language cannot be over-emphasised in teaching and learning. It is an important aspect through which students and teachers express scientific ideas. Language is indeed a fundamental factor not only to scientific language but also to all learning science (Hodson & Hodson, 1998b; Jones, 2000; Narayan & Wallace, 2003; Rollnick, 1998; Wellington, 2000). Rollnick (1998) argues that language is an issue that cannot be disregarded as it encroaches on the learning of science in many ways, which are related both to attitude and to cognition. In the study conducted on second language students of science, Rollnick (1998) claims that students may have language difficulties that could be rooted in other causes such as: (1) real language difficulties caused by a second language and nothing else, (2) conceptual difficulties, (3) cultural differences, and (4) educational and economic disadvantage. Further discussion about these aspects of language and science will not be attempted here because this has been well explained by Rollnick (1998) and others (e.g. Jones, 2000; Ogunniyi, 1998; Narayan & Wallace, 2003; Wellington, 2000).

Learning scientific language involves more than just being familiar with scientific terms. Scientific language is loaded and is not neutral at all. It involves the introduction of an individual to the thematic patterns of science (Hodson & Hodson, 1998b; Narayan & Wallace, 2003). Hodson and Hodson, (1998b) define the term ‘thematic patterns’ as those ways in which the scientific concepts and ideas are related to one another in a network of inter-dependence of meanings. They argue that new comers to a scientific community need to be introduced to distinctive features of scientific language, the use of technical terms and symbols and the use of familiar everyday terms in restricted and special scientific ways. They further claim that

> the notion of apprenticeship implies that students will learn the language of science by interaction with someone who is already an expert, and by using it themselves in carrying out authentic tasks. Thus, teachers should model appropriate language use, make explicit reference to its distinctive features, provide language-based activities that focus on them, create opportunities for students to act as autonomous users of the language, and provide critical feedback on their success in doing so (p. 22).

Insightful science learning as a productive communication process focuses on language and actions of students and teachers. Language becomes an essential social tool of communicating and interpreting science in general. Lijnse (1995) argues that when the teacher speaks in the language of science, even in simple terms, s/he cannot be understood as s/he intends to by students who do not know that language yet. In other words, it is unavoidable to understand one another during conversations in a social setting. In general, the teaching and learning process involves a mutual understanding between the teacher and the students. Knowledge is traditionally expressed through language, that is, knowledge is mediated through sentences, statements, and propositions (Jones, 2000; Staver, 1998; Vygotsky, 1978). In science, each word, concept, idea or statement has meaning and is linked to other such words and statements in a very special way (Ogunniyi, 1986a). It follows then that when the meanings carried in these statements, sentences and propositions are clear to students, the more they will understand and use the language during the learning process. Lijnse (1995) claims that teaching and learning need to be interconnected with the scientific language in order to allow students to carry out authentic tasks in science classrooms.

Sutton (1998) maintains that language is one of the scientific tools, which is used by the teacher on a daily basis. He argues that the teacher guides and facilitates the students' methodological inquiring thoughts through the medium of spoken and written language. Most of the teachers' talk is seen to mediate students' learning. Terms such as variables, planning, study, etc. are considered by some researchers (Ogunniyi, 1986a; Narayan & Wallace, 2003; Sutton, 1998) as having multiple meanings in everyday language and need to be clarified to students explicitly. It is essential for science teachers to show to their students how scientific terms are linked to one another and model methodological inquiry in their classroom practices. Command of scientific language, in particular, the methods of scientific inquiry, becomes an important aspect that students should acquire before they embark on their practical activities (Duran, Dugan & Weffer, 1998; Sutton, 1998). Sutton (1998) argues that learning of any kind involves acquisition and employment of new language in order to help students to make sense of what they think others are saying and what the students think others are seeing. He disputes the idea that when teachers are setting examples of how to use scientific language for different purposes, their students will experience the use of the language as a medium for conversation about the subject matter in question and that the students will start to use this understanding in classroom/ laboratory discourse to perform similar tasks.

Vygotsky (1978) extended the concept of tool mediation to include physical and symbolic objects. Mortimer and Scott (2000) on the other hand, argue that physical objects involve instruments such as pencils, calculators and other laboratory tools while symbolic tools are objects such as mathematical expressions and language as well as speech genres. They argue that in the science classroom, scientific and everyday language are presented and networked as ideas and phenomena which are talked about at different levels of understanding by both the students and teachers. Such talks between teachers and students form the source of classroom discourse (Christie, 2002; Davis, & Sumara, 2002; De Vries, Green, 2007; Lund & Baker, 2002). Wellington (2000) argues that scientific language also involves semiotics such as visual presentations which include images, graphs, tables, charts, models, diagrams, mathematical symbols and practical work where students use their sense of touch, smell, sight and hearing. He defines semiotics as a study of how "we make meaning by using words, images, symbols actions and other modes of communication" (p. 188). In science education, in particular, a variety of semiotics is used during practical work. In laboratory work, semiotics is utilised to illustrate collected data in various ways in order to allow individuals to analyse data easier.

As indicated earlier, laboratory tools or instruments as theorised by Vygotsky (1978) are considered to carry scientific knowledge within their very design. Nakhleh et al. (2002) argue that these tools may help students to acquire scientific knowledge only when the knowledge is evident to students. Interactions in the teaching and learning situations become important in order to make the scientific knowledge within these tools obvious to students. Nakhleh et al. (2002) further contend that unnoticeable information/knowledge within these tools will not help students to construct new knowledge when using these tools, that is, the tools become a sort of a mystery box when their uses and functions are not well understood. It is their view that when people interact with other human and material environment, they develop instrumental knowledge. Therefore, knowledge needs to be seen as being distributed across people to solve the tasks with which they are confronted with relative ease rather than when they work in isolation (Narayan & Wallace, 2003). Working within a community of science practices (e.g. a science classroom) gives rise to what Mortimer and Scott (2000) call "the classroom discourse" (p. 127). This setting tends to promote the sharing of the meanings of words, sentences, objects, in other words, scientific instruments in a variety of speech genres and in the social language prevalent in the teaching-learning process.

Qhobela et al. (2003) define discourse as a way of talking, writing, reading and doing things in a socially accepted manner within a particular community. In other words, in science education the scientific language refers to the role that this language plays during the classroom/ laboratory discourse. They argue that classroom discourse is based on teachers', students' talk, reading, writing and doing things. They also claim that enculturation into the scientific discourse means that teachers should assist their students to be enculturated into the practices of the scientific community. The idea here is that teachers should provide their students with the necessary cognitive tools which will in turn foster the students' thinking and problem-solving skills as well as enhance the process of enculturation. The next section deals with a variety of studies conducted in the field of science education in which scientific tools (including the scientific language) have been used to facilitate students' enculturation into scientific practices.

2.4 Scientific Knowledge versus Common Everyday Knowledge

Martin et al. (1997) describe science as a human construct and a human activity. In other words, science consists of a collection of human practical learning and everyday experiences - the meanings humans construct for themselves. It consists of three main parts:

- Scientific knowledge,
- Scientific attitudes, and
- Science process skills.

Scientific knowledge is depicted as consisting of facts, concepts, principles and theories. Sometimes it is referred to as products. Science knowledge is thought of as being tentative because it is changing over time although much of the science is relatively stable (Martin et al., 1997; Ogunniyi, 1986a; 1986b).

Hodson and Hodson (1998a) argue that scientific knowledge is more than personal belief which is strengthened by personally assembled observational confirmation. They contend that scientific knowledge attempts to explain and account for the real nature of the physical world. In other words, learning science should involve the introduction of the novices into the world of concepts, ideas, understandings and theories that scientists have developed and accumulated over the years. Gregory (2002) asserts that learning science is not a straightforward issue and is not simply a matter of making meaning of the physical world in whatever terms and for whatever reasons which may satisfy the student but a matter of cognitive scaffolding (Holton & Clarke, 2006) and learning the language of science. Scientific knowledge is both personally and socially constructed. According to Hodson and Hodson (1998a) scientific knowledge is

> Personally constructed in the sense that individual scientists devise theoretical constructs and impose them on physical entities in order to study and explain them; socially constructed in the sense that once these constructs have been agreed by the community as constituting valid knowledge, they are taken for granted until there are good grounds for doubting them (p. 38).

Ogunniyi (as cited by Fakudze, 2002) claims that scientific knowledge is based on facts, seeks empirical laws, principles, generalisations and theories. It is testable, falsifiable, tentative, anti-authoritarian and impersonal. It is a product of an open predicament. On the other hand, Driver et al. (1994) argue that scientific knowledge is both symbolic and socially agreed upon. They assert that scientific knowledge is constructed and communicated through the culture and social institutions of science.

The commonsense knowledge and informal science knowledge, on the other hand, are sustained by personal experience and socialization into commonsense views (Driver et al., 1994). They claim further that generally individuals use a range of knowledge schemes to interpret the phenomena they encounter in their daily lives. To them commonalities exist in informal ways of thinking simply because the members of a culture share ways of referring to and talking about particular natural phenomena. Hence, informal ideas are both personal views of the world and a shared view which is represented by a shared language that constitute a socially constructed commonsense way of describing and explaining the world. The commonsense knowledge differs from the scientific knowledge in a number of ways. Driver et al. (1994) describe these as follows:

- Commonsense and science differ in the ontological bodies they contain.
- Commonsense reasoning tends to have no explicit rules.
- Informal ways of thinking are characterised by pragmatism. In other words, ideas are reviewed in terms of their usefulness for specific purposes or in specific situations

and they are applied to guide people's actions (p. 8).

The two entities of knowledge as explained above have an implication for science teaching. Students do come to formal schooling with both sets of knowledge. Sometimes, the students tend to use commonsense views when they attempt to explain scientific knowledge. In science education, the uses of both knowledge entities create problems for students when trying to understand the natural world. In a developing country like Namibia, the students come to practical work classrooms with many common- sense ideas and informal scientific knowledge, and these in turn, sometimes hinder their scientific reasoning not only in understanding scientific knowledge but also in using the scientific language in explaining the natural world around them. The present study attempts to investigate the ways in which the Biology teachers used scientific language in order to enculturate their students into the Western scientific worldview during practical work.

2.5 Practical Work

2.5.1 Nature of Scientific Inquiry

The issue about the nature of science (NOS) is debated since the beginning of the science studies revival in the 1960s as a central component of science education (Rudolph, 2000; Solomon, et al., 1992). The NOS is expressed in various ways by different authors owing to its abstract and its interdisciplinary dimension, which cuts across the fields of sociology, philosophy, history, anthropology and phenomenology (Abd-El-Khalick & Lederman, 2000; Rudolph, 2000). Abd-El-Khalick and Lederman (2000) stated that the term 'nature of science' is used in reference to the epistemology of science as a way of knowing. They further argue that the conception of the NOS changes because of changes in the focus and emphasis in the field of philosophy, sociology and history of science. They sketch the gradual shift in the conceptions of NOS as follows:

- In the 1900s, the conception of NOS was based on the scientific method;
- In the 1960s, the focus was on enquiry and science process skills;
- In the 1970s, NOS was characterised as being tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic and empirical.
- In the 1980s, the definition of NOS included terminologies such as psychological factors, sociological factors and social discourse factors.
- In the 1990s, the emphasis of the NOS shifted and includes the historical, tentative, empirical, logical, the values of scepticism and open communication, and the interaction between personal, societal and cultural beliefs.

A review of literature on NOS shows the complexity of science as described in the two major science education reforms in the US, namely the Benchmarks for Science Literacy and the National Science Education Standards (Good & Shymansky, 2001; Solomon, Duveen, Scott & Mccarthy, 1992). They argue that the contrasting views, as observed in description of the NOS, are a result of the emphasis which is based either on postmodern/relativist view or on modern/realist view. They claim that the postmodern view of the NOS portrays science as a complex, viable process, producing knowledge which is stable and accurate while the modern view perceives reality as a social construct, nature as real and existing independently of humans and their diverse philosophical theories. Good and Shymansky (2001) further assert that

> Philosophy of science tends to emphasise the stable, rational, progressive, universal consensus nature of science while history of science tends to point out the unique, personal, variable, complex, local side of science and of course, both sides or viewpoints are correct. However, when compared to other ways of knowing or believing, modern science is by far the most progressive, stable, and rational way of knowing yet devised by humans and it is this side (modern/realist) rather than the other (postmodern/ relativist) that better characterizes the enterprise of science. (pp. 62-63).

Good and Shymansky (2001) argue that it is when the natural sciences are compared to the social sciences, the arts and humanities that the differences become so obvious. According to them, the disparities are more functional in introducing the new student to the NOS. The emphasis on the NOS is changing from a deductive to an inductive discourse and from an inductive to a deductive discourse (de Boer, 1991, p. 199). Logical reasoning in scientific thinking may be thought of as a continuum, one extreme being inductive and the other being deductive in reasoning. Kuhn (1962, p. 23) refers to such a transformation in logical reasoning as a “paradigm change”, a new way of viewing things or studying nature. When there is a paradigm change in the scientific community, evolutionary competitions also exist between the proponents of the new way of thinking and the old the normal-scientific traditional way of thinking. The movement or the ‘paradigm’ (Kuhn, 1962) within the scientific thinking sets up a challenge not only for the scientific community itself but also for science teachers when mediating learning in scientific inquiry. The paradigm change in science education also creates tension between ‘what’ should be taught to students about the NOS and ‘how’ teachers should teach the NOS to students. School science content covers mostly the history of science and very little (if anything) is mentioned about the philosophy of science.

The NOS is a complex concept and sometimes competing and conflicting views exist within the scientific community about it (Good & Shymansky, 2001; Rudolph, 2000). Harré (1970) identifies four main branches of discipline, namely, logic (the theory of reasoning), epistemology (the theory of knowledge), metaphysics (the theory of concepts and their relations) and ethics (the theory of moral evaluation). Canons and principles of reasoning are used in logical reasoning. They argue that some new piece of reasoning may be considered correct or incorrect by relating the concepts within the new reasoning to old concepts, which are found to be correct. On the other hand, Harrè (1970) claims that epistemology reflects on the standards to which true knowledge obeys the rules as operated by scientists.

A review of the literature reveals that the NOS should be seen as an umbrella which has different scientific conceptions and houses different ways of knowing the natural world around us (McComas, Clough & Almazroa, 1998; Ogunniyi, 1982). Hwang (1996) and McComas et al. (1998) and argue that the science educators describe the phrase NOS to mean the intersection of issues, which are addressed by the philosophy, history, sociology, and psychology of science as they apply to and impact science teaching and learning. McComas et al. (1998) and Ogunniyi (1982) claimed that the NOS should be considered as a fundamental domain to guide science educators to accurately portray science to students. The NOS as described above has educational implications for the training of science teachers. If science teachers are not trained appropriately to teach the NOS, they may not be effective in teaching the students about NOS. The teacher needs to make quick and informed decisions when providing cognitive apprenticeship to students during instruction. Hodson and Hodson (1998b) claim that cognitive apprenticeship is possible when students are learning alongside more experienced members of the community of scientists. They define cognitive apprenticeship as both a process of internalising knowledge and skills of individuals and as a process of becoming a member of the community of practice. They argue that the students will gain knowledge and skills by being given opportunities to learn alongside and to gain assistance, encouragement and support from teachers who have already been successfully enculturated into the scientific community.

All the terms mentioned earlier as entities of the NOS are intertwined and depend on one another in order to describe and organize the practical inquiry or the so-called ‘systematic body of scientific knowledge’ (Ogunniyi, 1982). Taking the complexity of the NOS into consideration the curriculum designers are put in a difficult position. Rudolph (2000) and Solomon et al. (1992) emphasise the difficulties that both educators and science curriculum designers face. Rudolph (2000) claims that it is hard to design a curriculum that reveals competing as well as contrasting views about the NOS. According to him, two essential problems need to be considered when including NOS issues into the science curriculum:

- The first problem is concerned with the match between the universal views of science and the structure of the school science curriculum which is based on traditional disciplinary distinctions. The conceptions of science are drawn from science studies or are simplified for curricular purposes and in so doing have sacrificed their ability to inform the specifics of any given disciplinary practice.

- The second problem is concerned with the growing concern about the validity of universal conceptions altogether.

McComas et al. (1998) believe that having appropriate knowledge of the NOS will enhance an understanding of the following scientific aspects in relation to classroom interactions for both the teachers and students:

- learning of science content,
- understanding how science operates,
- interest in science,
- informed decision making, and
- instructional delivery.

The NOS generally refers to the epistemology of science, that is, the values and assumptions that are inherent in the development of scientific knowledge and it is defined as a way of knowing (Abd-El-Khalick & Lederman, 2000; Laplante, 1997; Liu & Lederman, 2002). The term 'nature of science' may embrace the following concepts: scientific processes, scientific products, scientific ethics, regulative scientific principles and logico-mathematical systems. All of these are what is referred to as the so-called 'body of systematic knowledge'. Each of these terms has deeper meanings that enable these terms to differentiate science from any other field of study such as history, geography, other social science subjects and political science (Ogunniyi, 1986a; Solomon et al., 1992).

2.5.2 Scientific products

Scientific products contain the concepts of science such as facts, concepts, principles, laws and theories. These terms are linked to one another in very special ways and they depend on one another to explain different scientific phenomena or events. According to Jenkins (2001) scientific products are seen as the canon from the relativist point of view. Scientific knowledge is used to prove in a scientific way that new knowledge is valid and sound because of its links with proven concepts and principles. Although a discussion on scientific products is a very important matter when considering the application of process skills to solve problems, a detailed discussion of this subject is beyond the scope of this study. Hence, only brief remarks are made in this regard.

2.5.3 Scientific processes

The scientific processes describe the ways in which the scientific inquiry could be conducted (Hall & Hall, 1996; Ogunniyi, 1986a) and comprise of the following ways of knowing:

- Inductive,
- Deductive,
- Inductive-deductive, and
- Practical reasoning.

The above-mentioned ways of thinking express a paradigm in the methods of thought. Hall and Hall (1996) maintain that inductive reasoning is based on observed facts that results in more general theories that can never be totally proven. Inductive reasoning starts from specific observation and develops into theories. Hall and Hall (1996) argue that observation in itself is a subjective and an interpretive process. On the other hand, deductive reasoning starts from general problem into specific concepts or hypotheses that are related to one another through fundamental models (Ogunniyi, 1986a). For example, scientists as humans are engaged in science activities which might result in solving a particular societal problem, although this is not the primary aim of conducting scientific inquiry. Scientists generally have a propensity to define a problem and find ways in solving it. Whether or not the result has practical implications is a secondary concern. However, whilst engaged in finding a solution to a given problem they may use either an inductive or a deductive approach or both (Hall & Hall, 1996). One may say that there is no one simple method, which is followed by a scientist. It is a matter of preference. Nevertheless, even this preference is not a haphazard activity; it is based on practical reasoning (Hattingh, Aldous & Rogan, 2007). Millar and Driver (1987, p. 34) suggest that science processes should be used to introduce students to the methods of science as well as to equip them in the following aspects of scientific processes:

- Make observations,
- Seek and identify patterns relevant to their investigations for further study,
- Suggest and evaluate explanations of the patterns,
- Design and carry out experiments, including appropriate forms of measurement, to test suggested explanations for the patterns of observations,
- Communicate (verbally, mathematically and graphically) and interpret written and other materials,
- Handle equipment safely and effectively,
- Bring their knowledge to bear in attempting to solve technological problems.

They assert also that the activities above should form a part of scientific inquiry during classroom/ laboratory interactions. To them, the above activities are crucial in assisting students to acquire an understanding of the concepts involved in scientific methods during laboratory sessions.

2.5.4 Scientific ethics

Scientific ethics is another aspect of the nature of science. Ogunniyi (1986a) notes that this aspect deals with the code of conduct of scientists. The code of conduct of scientists describes scientists' characteristics such as their behaviours and attitudes in relation to their work. He considers the scientists' behaviours and attitudes to include the following aspects: intense curiosity, scepticism, objectivity, open-mindedness, humility, honesty, and determination. Ogunniyi (1986a) states that scientists should try to be honest, careful and objective in what they say or do. He argues that the mentioned scientific attitudes and behaviours are essential not only because the scientist will be scrutinized by others but also to permit others to ascertain the validity of his/her findings. Ogunniyi (1986a) contends that science does not respect authority; it does respect testable facts. Hence, a scientific idea or skill that is not subject to critical examination is not respected in the scientific community. In Ogunniyi's (1986a) view the ethics of science underpin how scientists behave and act when engaged in an inquiry. It is, therefore, imperative that a scientist demonstrates great care in his/her observations, data collection, recording or reporting. Hodson (1993) refers to the scientific attitudes as those approaches and attitudes towards information, ideas and procedures which are considered essential for the practitioners of science. Although scientific attitudes have a high priority in the school science curriculum, Hodson (1993) claims that practical work as provided in schools is unlikely to promote these scientific attitudes.

This study, however, focuses on the processes of science and the language used during practical activities to draw meaningful inferences. School laboratory work is an aspect of the science curriculum in which students are exposed in a small way to scientific inquiry. It is a setting in which students begin to learn how scientists carry out scientific investigations. Many curricula reforms worldwide have emphasized the need for students to acquire process skills which are critical to conduct scientific inquiry. For example, the Namibian Biology syllabus requires teachers to teach such skills to their students (MEC, NSSC-H Level syllabus, 2006).

2.6 Process skills

One of the important debates in science education is centred on laboratory work. Some researchers (Donnelly, 1998; Hattingh, et al., 2007; Hodson, 1996a) argue for the place of the laboratory in school science while others are against its use.

Donnelly (1998) maintains that much of the recent debates on laboratory work, however, are positioned in the somewhat abstract analysis of the nature of scientific practice. He claims that the recent debates focus on educational aims, scientific epistemology of laboratory work and the pedagogic methods of laboratory work.

The term 'practical' is used in various ways to mean different things in everyday language. For example, 'Vijanda, you are not being practical at all now' (adjective), 'let us do the theory in the morning hours and practical in the afternoon hours (noun)'. Teachers generally know the difference between a normal class theory teaching and practical work but this notion differs from teacher to teacher. Sometimes written work is also considered a part of practical work. Donnelly (1998) found that the term practical work appears not to have the same meaning for the teachers and students. He also notes that some teachers conduct practical activities for the sake of them while other teachers conduct practical activities when the need arises. He contends that the physical place and the time spent in the laboratory are essential in order for teachers to conduct practical work.

Pella (1969) refers to laboratory work or exercise to include instructional procedures in which an individual determines the cause and effect, nature or property of any object or phenomena under controlled situations. He also argues that demonstrations are often included in laboratory activities. He identifies eight functions that can be related to laboratory activities:

- A means of securing information,
- A means of determining cause and effect relationships,
- A means of verifying certain factors or phenomena,
- A means of applying what is known,
- A means of developing skill,
- A means of providing drill,.
- A means of helping pupils learn to use scientific methods of solving problems, and.

- A means of carrying an individual research (p. 234).

Pella (1969) further argues that these eight laboratory functions are important and are directly related to the nature of the learning outcomes. Although Pella's work dates from more than four decades ago, these learning outcomes are still relevant. The learning outcomes, as described by Pella and those found in the science curriculum outlines of many schools, stress some common aspects such as: (i) the methods of science (processes), (ii) the scientific attitudes, interest in science, (iii) application of scientific concepts, (iv) the development of an appreciation for the growth scientific knowledge and (v) the development of scientific knowledge (MEC, NSSC-H Level Biology syllabus, 2006). Pella (1969) observes that such similarities are expected because the learning outcomes are the products of investigations while the functions involve the processes, which are used to arrive at the scientific knowledge.

However, Hodson (1996a) maintains that the term 'practical work' is found in a diversity of practices and organisational outlines. This broad description of practical work may bring confusion to teachers and researchers as mentioned by Donnelly (1998). There is a need for teachers or researchers to link the aims of practical work with one or more kinds of activities (e.g. written work, problem-solving exercises, special exhibitions, science competitions and simulated experiments). He further asserts that teachers may over-use or under-use practical work unknowingly. For instance, teachers may not fully exploit the real value of practical work simply because they do not have a clear picture of what they should focus on when facilitating project work. On the other hand, Hodson (1996a) claims that practical work may be over-used by teachers by simply assuming that practical work could be used to achieve all learning goals.

Most practical activities are used for teaching process skills. Martin et al. (1997) observe that in science education the processes comprise ways of thinking, measuring, solving problems and using thoughts. They claim that process skills describe the type of thinking and reasoning required when students are involved in science inquiry. Hodson (1992) refers to such skills as those “skills of carrying out the strategic processes of science” (p. 68). Process skills comprise:

- practical skills,
- basic skills,
- integrated skills, and
- skills of the concepts of evidence.

The practical skills are simple skills and are referred to as experimental or technical skills which are needed in handling apparatus and materials as well as knowing how to draw graphs and tables. The basic skills are process skills such as observing, classifying, communicating, measuring, estimating, predicting and inferring. To Martin et al. (1997) the basic skills are generally used independently from other skills while integrated skills are a combination of the basic process skills that are used simultaneously in order to think at higher levels and to consider more than one thought at a time.

Gott and Duggan (1996) consider the concepts of evidence to include practical skills such as (i) variable manipulation, fair testing, sample size, variable types; (ii) accuracy, repeatability, choice of instrument, relative scale, range of interval; (iii) data handling in terms of the use of tables, graph types and patterns; (iv) validity and reliability of data. They also assert that the concepts of validity and reliability “overarch all the other concepts of evidence” (p. 795). For example, in order to evaluate the validity of evidence, one has to evaluate all the other concepts. The acquisition of these skills seems to be useful in the society, and in engineering and science education. Such skills deal with logic about how, for example, an individual may use logic to decide on a particular skill that will assist the individual to solve a specific task/problem.

Procedural understanding is concerned with the use of procedural skills at various degrees of thinking in experimental and investigative work. For example, an individual may show different understandings about the procedures of experimental work by identifying variables as well as understanding their importance in relation to the practical task. Such an individual may also decide to use a particular measuring instrument that she/he thinks will provide her/him with reliable data (Gott & Duggan, 1995; Hodson, 1996b; Martin et al., 1997; Roberts & Gott, 1999; Tobin, 1984). This notion of practical skills accords with Norris' (1992) idea of practical reasoning often used by scientists while conducting an investigation.

Lubben and Millar (1996) suggest that school science education must teach students an understanding of the processes of scientific enquiry. They argue that practical work in science must help students to develop an understanding of the procedures of scientific enquiry. Sadeck, Scholtz and Johnson (2003) conducted a study of pre-service South African college teachers on their scientific literacy skills. The findings showed that the scientific literacy rates on process skills of these teachers were very low. They asserted that procedural skills were not taught at the formal school level in South Africa and this was reflected in the performances of the students. They were of the view that if these skills were taught at all, they were done only to a limited extent.

The findings from a study conducted by White (2003) showed similar results in relation to a sample of Biology teachers who showed a wide range of difficulties with the process skills such as formulating hypotheses, interpreting graphs, mathematical calculations, measurement, making inferences and classifying. Although most teachers from this group could interpret a pie chart and/or other charts, they had difficulties in interpreting line graphs. Most of them found it difficult to formulate hypotheses, design a fair test and distinguish between dependent and independent variables. They have also had difficulties with abstract concepts such as ratios and proportions.

Roberts and Gott (2000) conducted a study on how procedural ideas were presented in various textbooks, associated students' guides and other resource materials. The procedural ideas as presented in textbooks included the following features:

- designing investigations,
- collecting of experimental data,
- presenting and analysing of experimental data, and
- evaluating of the resulting evidence.

The findings showed that references to procedural ideas implicitly occurred almost entirely in all the activities regardless of whether or not they were practical work. The findings also showed that procedural ideas were explicitly said to a minor extent. The teaching resources, where procedural ideas are implicitly shown, have implications for teaching because the teacher may not be effectively guided by implicit scientific ideas. Such scientific ideas need to be explicitly described in teaching and learning resources. However, Roberts and Gott (2000) were of the view that a range of procedural ideas used by biologists was excluded in the practical work that was analysed. They asserted that such practices might lead to a misrepresentation of the procedural ideas that are important in Biology.

Following from the above information in relation to the teaching and learning of process skills, Chacko (1997) also reported that in some cases the students are not provided with opportunities in order to develop procedural understanding because all activities were simple illustrations and, hence, not set up to assist the students to design and carry out practical activities. While in another study conducted by Lubben and Millar (1996), the students were reported to understand the process of measuring better as they grew cognitively. Such a progression in understanding starts with a “denial of the need to repeat measurements, via a search for recurring results and a deliberate variation of control variables to collect a guaranteed variety of results, to the determination of the likely range of results” (Lubben & Millar, 1996, p. 964).

There seems to be a relationship between the teachers’ understanding and the difficulties that students experience relative to practical work. If teachers themselves experience some degrees of difficulties to involve students in practical work, what then, are the students gaining from such a learning environment? This issue certainly warrants a closer consideration by investigators concerned with practical work in school science. I hope that this study will provide some insight into the area based on the observed laboratory sessions.

2.7 Aims of doing practical work

The aims of practical work are the focus of many research discussions. After more than four decades the motives of the aims of practical work have remained unchanged as shown by Kerr in 1963, although there is a relative shift in the priorities. In some cases, researchers discuss the role of practical work in school science while in others the focus is on the aims of practical work as well as on the nature and origin of practical work in the school science (Bennett & Kennedy, 2001; Gott & Duggan, 1996; Harlen, 1999; 2000; Hodson 1990; Kerr, 1963; Swain et al., 1999; Woolnough & Allsop, 1985). Hodson (1996a) identifies three kinds of learning in terms of process skills, namely:

- enhance conceptual understanding of what is being studied/ investigated,
- enhance procedural knowledge where students learn more about experiments, and
- enhance investigative expertise under guidance of a skilled professional teacher.

In addition to the above-mentioned aims, the students are provided with opportunities to report, debate and support the findings of their experimental results during investigations. Furthermore, Hodson (1990) suggests five reasons as to why teachers involve their students in practical activities, namely:

- To motivate, stimulating interest and enjoyment,
- To teach laboratory skills,
- To enhance the learning of scientific knowledge,
- To give insight into scientific method, and develop expertise in using it, and
- To develop certain 'scientific attitudes', such as open-mindedness, objectivity and willingness to suspend judgement (p. 34).

Hodson further asserts that the acquisition of skills in practical work cannot be developed without linking it to scientific content. According to him, the development of content-free scientific skills is not possible and should not be encouraged. Teaching laboratory skills should have a purpose of engaging students in other worthwhile activities and should not simply be to teach students skills irrespective of whether or not they are needed for future learning. Hodson (1990; 1996a) argues that the primary purpose of practical work should be considered as the acquisition of practical skills. His view is that teachers should be clear about the aims of practical work and what practical activities go along with which aims.

Bennett and Kennedy (2001) claim that there is a vast variety of practical aims and that the situation makes assessment of practical work very difficult. It is obvious that there will be confusion among the educators because of the variety of practical activities as compared to different aims that exist. They claim that it becomes essential for teachers to make links between activities and their appropriate aims in order to teach effectively. They also claim that practical work is prevalent in the school science curricula of many countries but there are still no agreements as to what the nature and purpose of the activities should be and what ways of assessment are more reliable and valid to test practical skills and abilities. According to some authors (Bennett & Kennedy, 2001; Gott & Duggan, 2002; Jegede, & Olajide, 1995) assessment of practical work focuses on: (1) manipulative skills and techniques, (2) accurate observation and description, and (3) data collection, presentation and interpretation while assessment on illustrating a concept, law or principle and on how to stimulate interest, enjoyment and scientific attitudes are rarely tested.

Bennett and Kennedy (2001) conducted a study in which three different assessment models were considered, namely: teacher assessment (continuous practical work assessment), end of year examination (practical test) and assessment of practical work by a visiting examiner and an external moderator.

They found that written examinations in practical work assessment mostly focus on the lower levels in the cognitive domain (knowledge, comprehension and application) and not on assessing the key areas in the higher cognitive domain (analysis, synthesis and evaluation) in relation to Bloom's taxonomy which is central to practical work. This is in line with Chacko (1997) who found that practical work manuals have not aims and the focus of teaching is simply on developing low cognitive reasoning rather than the high level reasoning. The findings of the study also showed that test items on the affective domain were not included in the assessment models.

On the other hand, Maboyi and Dekkers (2003) assert that the purposes of practical work focus more on confirming scientific events and phenomena rather than on investigating and interpreting data. This is also, in line with what Kapenda et al. (2001) indicate in relation the roles of practical work in the secondary schools in Namibia. This may mean that teachers are only emphasising the conceptual understanding rather than developing procedural and/or conceptual knowledge. Maboyi and Dekkers (2003), suggest that the role of the teacher is crucial since she/he is one of the determining factors in what is intended to be taught during instruction.

The findings of a study conducted on Natural Sciences teachers in the Soutpansberg West circuit in South Africa by Maboyi and Dekkers (2003) showed that the teachers preferred teacher demonstration rather than small group instruction because of lack of resources and overcrowded classrooms. In addition, most prescribed practical activities were not conducted but were dealt with verbally. They claimed that the majority of practical activities focused on how to demonstrate, identify, verify and prove selected scientific ideas, concepts or principles; that is, confirming scientific events and phenomena.

2.8 Types of Practical Activities

Brown (1995) and Woolnough (1994) maintain that practical work involves the following activities:

- hands-on experiments;
- observations;
- demonstrations;
- groups discussions;
- pencil-and-paper class work/ exercise and
- projects.

The list of activities above also includes investigative work such as guided and unguided inquiry work, for example to plan and carry out investigations as well as practical activities that include illustrations of scientific theories and concepts (Parkinson, 1994; Woolnough, 2000). In addition to these activities, Millar et al. (1999) include the handling of real objects or materials by simulation or video recordings.

Nakhleh et al. (2002) also assert that research conducted on the value of practical work at both tertiary and secondary levels has changed over time from the traditional lecture demonstrations to the individual students' laboratory work. Their view of the existing literature shows that there is no significant difference in teaching science content through the lecture, demonstration or laboratory work. However, the results showed that students who were taught through the laboratory method outperformed other students in relation to the acquisition of technical skills when working with instruments. They asserted that such open-endedness in a research design would be more appealing in dealing with the intricacy of practical work environments.

2.9 Scientific inquiry and investigation

The term inquiry means different things to different people according to their perceptions or their worldviews. Wheeler (2000) describes the term as an elastic word that can be stretched to have a variety of meanings. He described three types of inquiry activities, namely

- inquiry – engaging students in hands-on activities. Not all hands-on activities are inquiry-based and meaningful learning is not guaranteed;
- inquiry - engaging students with materials by doing experiments. Activities involved in experimentation are observing, asking questions, making inferences or predictions and thinking about how to process the results from experiments;
- engaging students in the process of inquiry, that is, inquiry becomes the content to be taught (Wheeler, 2000).

On the other hand, Bybee (2000) uses inquiry to refer to the "methods and processes that scientists use during scientific inquiry" (p. 37). He argues that inquiry as a process is a set of cognitive abilities that the students should develop to solve problems but it can also be used as a teaching strategy that can facilitate learning of scientific inquiry. He claims that scientific inquiry can be used to develop inquiry abilities in order to enhance the development in understanding the scientific concepts and principles. However, Keys and Kennedy (1999) define scientific inquiry as the "activities of learners in which they develop knowledge and understandings of scientific ideas as well as an understanding of how scientists study the natural world" (p. 315). They assert that scientific inquiry focuses on the students' prior knowledge and their active engagement with the physical, social, cultural and technological environment (Hewson & Hewson, 1988; Johannessen, Harkin & Mikalsen, 2002; Johnson, & Lawson, 1998; Klopfer, 1990).

Furthermore, Keys and Kennedy (1999) contend that inquiry is multi-facetted and it involves observations, posing questions, examining books and other sources of information to see what is really known, planning investigations, reviewing what is already known in light of experimental evidence, using tools to gather, analyse and interpret data proposing answers, explanations and predictions and communicating the results. This definition seems to be too broad and seems to provide little assistance to science teachers, that is, it becomes very difficult to transform these skills into teachable activities. The teachers will find it difficult to use this information in planning lessons, teaching and evaluating inquiry in science classrooms. According to Bybee (2000), science can be taught as an inquiry or through science content or inquiry as a teaching strategy. The former develops the abilities and understandings of science inquiry and at the same time, learning is focused on the fundamentals of science as content. The latter involves activities such as experiments, fieldwork and inquiry initiated by students' curiosity.

Bates (as cited by Nakhleh et al., 2002) finds that some kind of inquiry-oriented laboratory activities to be better than the lecture or lecture demonstration of practical work in relation to teaching the process of inquiry. However, Bates propounds that teachers need to be skilled in teaching inquiry methods in order for the students to reap the benefits. Similarly, Hodson (1996a) asserts that practical work is difficult to teach and both in-service and pre-service training need to be conducted in order to provide science teachers with the special skills they may need to organise practical work effectively.

McNally (2000) argues that there are three ways in which science investigation can be integrated into classroom practices, namely: investigation activities may be added on as a whole separate class exercise; it may be added on through pre-writing investigative activities that are part of normal class; or investigation problems may be supported as they arise in an informal way from the students. The findings of a study conducted by Gangoli and Gurumurthy (1995) showed that a guided open-ended approach was superior to the traditional laboratory approach in developing cognitive skills such as knowledge, understanding and application as well as practical skills.

Watson et al. (1999) maintain that there are different kinds of scientific investigations. They identify six different kinds of investigations, namely:

- classifying and identifying;
- fair testing;
- pattern seeking;
- investigating models;
- exploring; and
- making things or developing systems (p. 102).

Classifying is seen as a process through which a large range of phenomena, objects or events are arranged into manageable sets while identifying refers to a process through which objects or events are recognised as members of a particular set. Fair testing is concerned "with observing and exploring relations between variables" (Watson et al., 1999, p. 103). The focus in fair testing is on identifying one or more variables (independent and dependent) and keeping these variables constant throughout the investigation. An independent variable manipulated independently in relation to other variables is controlled for a fair test. They assert that during such an investigation, procedures are identified and manipulated in order to observe, measure or control a number of other variables. Furthermore, Watson et al. (1999) describe pattern seeking as a process through which the natural events are observed and recorded. They claim that in pattern seeking the

> dependent variable is identified first, that is, an effect is noticed and the investigation is structured around finding a possible cause for the effect. Variables are still identified within a natural setting but the variables (factors) are not easy to control (p. 103).

According to them scientific exploration is identified from other explorations by determining the purpose of the exploration. The purpose should be scientific in nature, for example, the students may observe and record the behaviour of a cat during a different time of the day. They assert that students could be allowed to study previous scientific models within the subject they are studying. They also maintain that such practical activities might allow students to collect evidence in natural settings and try to explain how scientists arrive at decisions. Watson et al. (1999) claim that the process of testing scientific models is considered to be essential to the students in order to "develop insight into relationships between evidence and scientific models" (p. 104). Making things and developing systems is another type of an investigation They futher consider important too. The students can design and produce artefacts or systems, which could be used to meet human needs. The students may use their knowledge of science to design and produce objects that are needed for human consumption.

Student-centred activities comprise projects, group practical work and individual practical work while teacher-centred activities could be teacher demonstrations where students could assist the teacher during demonstrations or simply watch what the teacher is doing (Chacko, 1997; Jegede, & Olajide, 1995). During the project activities and group practical work, the teacher could provide guidance or the students could be guided by other students in order to complete the activities (guided investigation and investigations).

2.10 Instructional strategies in science classroom

The term constructivist teaching is commonly used in the teaching and learning situations. It is not used to mean that the teacher is constructing knowledge for the students but rather it refers to the many responsibilities given to the teacher during instruction (Brooks & Brooks, 1993; Duit & Treagust, 1998; Richardson, 1997; Watt et al., 1997). Watt et al. (1997) put it as follows:

> it is a matter of balance and their range of teaching strategies and techniques must vary across a wide spectrum, from overt classroom control to covert conceptual change again. While there must be room for input, exposition, explanation, demonstration, description, direction, reference, showing, modelling…, the overall balance must be towards teaching-as-managing, not teaching-as-telling (p. 310).

Tobin, Tippins and Gallard (1994) observe that the role of the teacher changes from that of transmitting knowledge in monitoring students' understandings, guiding discussions by using the scientific language to engage students in classifying, elaborating, justifying and evaluating alternative points of view in the constructivist ways of teaching. Under these conditions, the teacher needs to have appropriate information concerning the content she/he is teaching in order to perform her/his roles effectively.

The following are some examples of the ways in which the teacher can provide opportunities for students to work under a more constructivist environment that can enhance the students' active role in learning science knowledge.

2.10.1 Mediating learning through verbal interactions

One of the roles of teachers in a constructivist perspective-learning environment is for them to mediate student's learning (Haney & McArthy, 2002; Jegede, & Olajide, 1995; Kalu, 2005; Tobin et al., 1994). Mediating can take many forms such as managing learning, providing clarity of content, questioning as well as providing enough 'wait-time' (defined below). They assert that 'wait-time' provides students with an opportunity to reflect on what is discussed or to transfer control from one person to another within classroom discourse. For example, when the students are given a chance ('wait-time'), they internalise what is asked and start to formulate answers in their minds on how they will respond to the question, which was posed.

Tobin et al. (1994) argue that each word, spoken or written, needs to be heard and assigned meaning by the students. Similarly, in science education each word, statement, phrase, concept, fact, etc. has a scientific meaning that needs to be mediated to the audience, in this case the students. They define 'wait-time' as the "duration of the pause after a teacher utterance or a student utterance" (p. 71). They further assert that teachers who have longer 'wait-times', have improved the teaching quality and have "demonstrated greater response flexibility, ask fewer and more appropriate questions and develop high expectations for students” (p. 71).

2.10.2 Apprenticeship

Apprenticeship is defined as a process through which individuals become members of a certain community by internalising knowledge and skills as practised in that community. Hodson and Hodson (1998b) observe that individuals new to a group pick up relevant social language by imitating behaviours of skilled members and gradually start to behave in accordance with community norms and values. The more those knowledgeable coach, guide and support the less knowledgeable, the better the chances for the latter to appropriate what is taught. Certain aspects of practical work in Biology Education will, of necessity, be demonstrated because of the risks involved in the experiments. In such cases, the students as apprentices would need to observe the teacher while conducting the experiments.

2.10.3 Scaffolding

Hodson and Hodson (1998b) describe scaffolding as a purposeful interventional act from the side of the more knowledgeable person. Such a person is seen to control the learning tasks in order for the less knowledgeable person to perform a certain task or achieve a certain aim. The person offers guidance, which is needed at the time (Holton & Clarke, 2006). Hodson and Hodson (1998b) further identify a three-phase approach to providing scaffolding in a formal setting, namely:

- Modelling- where the teacher exhibits the desired behaviour;
- Guided practice- where students perform with help from the teacher; and
- Application- where students perform independently of the teacher (p. 20).

2.10.4 Modelling

Modelling refers to a process where the teacher performs the learning task by acting as an expert student (Hodson & Hodson, 1998b). For example, in the laboratory setting, the teacher will demonstrate a task to the whole class or to a small group and thereafter, the student may perform a similar task in the presence of the teacher. Hodson and Hodson (1998b) note that the constructivist perspective offers some pointers to assist students in the task of conceptual reconstruction, namely:

- To identify students' ideas and views;
- To create opportunities for students to explore their ideas and test their robustness in explaining phenomena, accounting for events and making predictions;
- To provide stimuli for students to develop, modify and, where necessary, change their ideas and views; and
- To support their attempts to re-think and reconstruct their ideas and views (p. 34).

In order for students to rethink and reconstruct their previous mental structures, they must first be dissatisfied with their current beliefs/understanding. According to Posner, Strike, Hewson and Gertzog (1982) the new idea must meet certain conditions in order to be acceptable to the student. These conditions are:

- the idea must be intelligible – the student must understand what it means, how it can and should be used;
- it must be plausible – it should be consistent with and be able to be reconciled with other aspects of the student's understanding; and
- it must be fruitful – it should have the capacity to provide something of value to the learner by solving significant problems or suggesting new explanatory possibilities (p. 34).

Under the constructivist perspective, the students reshape the role of the teachers to fit the active construction and restructuring of knowledge. The teachers' role becomes that of a guider, provocateur, creator-of-opportunity and co-developer of understanding with students (Gregory, 2002; Kempa, & Ayob, 1991; Windschitl, 1999).

However, the content is seen as a very important variable because the students' beliefs affect what they are learning from instruction. According to Gunstone and White (2000) beliefs are content-specific and students had to learn something. The common notion is that beliefs formed from experiences could prevent further learning. They further argue that beliefs which are not in line with scientific explanations are not so because of isolated instances of poor teaching but because of common experiences and interpretations of these experiences. Such beliefs become challenges for teachers and researchers to look for effective ways in order to challenge students' alternative beliefs. A set of principles that may provide relevant information to teachers on alternative conceptions are the following:

- Learning involves the construction of meaning;
- Existing knowledge and experiences affect the meanings constructed;
- Different people have different knowledge, so are likely to construct different meanings from the same information;
- There are patterns in the meanings students construct owing to shared experiences of the natural world;
- Good teaching involves checking before instruction on students' prior meanings;
- Good teaching involves checking on students' constructions of meanings following instruction;
- The more abstract the concept, the less it is open to direct experience, and the less likely that learners will come to the classroom with alternative conceptions of it;
- Discussion of students' beliefs will be advantageous for topics that are open to experiences and concrete, and harmful for topics that are closed to experience and abstract;
- The more complex the topic, the greater the need to attend to integrating it and to showing its unity;
- The incidence of alternative conceptions will be greater for topics that employ specialized use of common words; and
- Rote learning will be more prevalent in topics with a high proportion of unfamiliar words (Gunstone & White, 2000, pp. 300-301).

2.11 Studies on practical work in science education

The following sections focus on studies conducted on some themes related to practical work in science education.

2.11.1 Aims and objectives of practical work

Bekalo and Welford (2000) conducted a study to examine intended and implemented learning outcomes in secondary physical science curriculum in Ethiopia. The aim was to investigate the uses of the problem-solving approach in laboratory work. The findings showed that there was a mismatch between the intended and the implemented curriculum. They further reported that the students rarely conducted practical work and teachers rarely involved students in demonstrations. According to Bekalo and Welford, such mismatches are found in the school science curricula of many African countries. They noted that mismatches could be attributed to a variety of factors such as the lack of awareness and understanding of the role and purpose of a range of practical activities, poor teacher education training, poor physical resources, teacher assessment procedures, and the lack of on-going support to teachers by educational authorities. The study also revealed that there was no link between what was stated in policies and what was realized in classrooms; and learning activities were not coherent with the stated learning outcomes. As a result, students did not receive practical experiences aligned with the aims specified in the official science curriculum.

Swain et al. (1999) explored students' attitudes to aims of practical work in science education in three different countries: Egypt, Korea and UK. It was found that all three groups of students expressed a common attitude towards the aims of practical work, and in particular, to "the methods by which scientists produce new knowledge". Swain et al. (1999) reported that the three groups of the students agreed that empirical work should be considered the defining features of science and all three groups ranged the aim about "to encourage accurate observation and description” the highest. This aim was followed by “to practise seeing problems and seeking ways to solve them”; “to arouse and maintain interest”; “to make phenomena more real” and “to find facts and arrive at new principles”. They further describe some differences in attitudes towards the aims of practical work amongst the three groups of students. Swain et al. (1999) suggested that the differences could be attributed to limited laboratory work, the lack of manipulative techniques and overcrowded classrooms.

Thompson (1975) investigated the value of practical work at the upper secondary school level in England and Wales. The aim was to determine the value that teachers placed on laboratory work and to find out the constraints that prevented teachers from putting theory into practice. The finding revealed that teachers provided opportunities for students to be involved in a variety of practical work such as standardized exercises, discovery experiments, and taught those aims that they considered important such as training of competent technicians, provision of laboratory facilities, lightening the load of laboratory timetable, success in examinations and reducing the size of the class. It was also found that there was a shift in the emphasis placed on particular aims of practical as reported by Kerr (1963). Thompson (1975) reported that the teachers were in an agreement with the principle aims of practical work to be: “to encourage accurate observation and description”, “to make phenomena more real through experience” and “to promote a logical reasoning method of thought”. However, it was found that biology and physics teachers placed greater emphasis on the development of critical attitudes. Thompson (1975) noted that teachers placed more emphasis on practical work as a means of making phenomena more real through experiences.

2.11.2 Teachers’ views and beliefs of their practices

Ramorogo (1998) explored teachers’ perception of practical work in Biology in Botswana secondary schools using a questionnaire. The findings showed that teachers conducted practical work only for didactic reasoning. It was reported that most of the practical lessons in Biology were dominated by laboratory activities that required the students to make accurate observations and measurements, use scientific apparatus correctly and confirm and verify facts and principles. He observed that the nature of how practical work was conducted in Biology classes rarely created opportunities for students to be engaged in critical thinking, evaluation of ideas or negotiating and reaching of consensus. Ramorogo further remarked that such practices denied students the opportunities to create knowledge in the course of social interactions. According to him, laboratory activities with the potential to engage students in active construction of knowledge were least utilised in Biology classes. He also reported that large classes, the shortage of laboratories and the lack of laboratory assistants could be serious impediments to teachers in involving students in meaningful practical activities (Keys, 2007; Laplante, 1997).

Cossa, Holtman, Ogunniyi and Mikalsen (2005) explored the understanding of students' perceptions about the role of practical work in learning Cell Biology. The purpose of the study was to evaluate how practical work could contribute to the teaching and learning of Cell Biology. The finding showed that there was a common understanding among the students and that their conceptual knowledge, intellectual skills, procedural knowledge and investigation skills had improved extensively. The lecturers remarked that the practical work contributed significantly in helping students to link theory with practice as well as enhancing students' ability to manipulate laboratory equipment and instruments. However, they reported that divergent ideas between students' actual practices relating to their opinions of practical work. They suggested that lack of laboratory materials/ chemicals, conducive working conditions, link between laboratory work content and previous theory, large number of students, appropriate teaching methodology, well-printed practical guides and the amount of laboratory time were some of the aspects that needed to be taken up seriously in order to improve the teaching-learning process in laboratory classes.

2.11.3 Constraints with practical work

Dumisani and Sanders (2003) conducted a study on students' difficulties with drawing graphs. The purpose of the study was to investigate and set up a programme to improve students' ability to construct and interpret graphs. They maintained that students' ability to work with graphs was superficial and was based on the application of rules of graphing rather than on the conceptual understanding of the functions of graphs. The findings also showed that most of the students were unable to apply graphical grammar for the coding and decoding of information in a graph, were unable to link the graphical information with variables being depicted, and lacked appropriate understanding of how substantive concepts were being graphed.

Sanders and Khanyane (2003) carried out a study to investigate how the students in Biology interpreted textbook diagrams. They discovered that students often found it difficult to visualise abstract information presented in pictorial form. They further reported that the majority of the students lacked visual literacy skills, did not make use of adjacent explanatory text, captions or headings, and interpretations were not in accordance with the evidence provided. In addition, they reported that some vital information from the diagrams was missing; diagrams were poorly spaced and the outline of diagrammes was unclear to students. To Saunders and Khanyane (2003) pictures illustrate abstract processes and microscopic structures to the students in Biology. For example, a picture or a diagram may represent more than one process and /or concept at a microscopic level. It is also a new language to students and hence, the students need to be sensitised by teachers into these kinds of phenomenal representations. Moreover, the students will not automatically learn new information by simply looking at a picture.

Haambokoma (2007) conducted a study on errors that students made when answering questions in Biology practical tests in schools certificate examination in Zambia. The findings of the study showed that the students made different mistakes with respect to drawings, labelling, measuring, recording, calculating magnifications, comparing and contrasting specimens as well as carrying out food tests. The following errors were reported with reference to food testing:

- Most of the students failed to specify the quantity of the reagent used;
- Students used inappropriate methods of heating or failed to specify the method of heating;
- Giving wrong colour change;
- Heating after the addition of iodine solution;
- Inaccurate description of observation;
- Making incorrect deductions from observations; and
- Using wrong testing procedure.

Haambokoma (2007) concluded that the above-mentioned errors were indications that the students had low understanding of practical work and mastery of experimental skills. He further remarked that teachers were sometimes a contributing factor as they seemed not to provide students with enough opportunities to practise and develop the necessary understanding of practical work and mastery of experimental skills. He further observed that the lack of adequate feedback to students on their practical work could also contribute to the lack of improvement in the errors mentioned above. Other factors that could contribute to the errors cited above are the inadequate training of teacher as well as an overloaded Biology syllabus. Because of these factors teachers tend to use theoretical methods in order to cover the vast syllabus before the examination.

Cossa (2006) carried out an investigation on university lecturers' laboratory work teaching experiences, practices and views of the aims of laboratory work in Biology courses. The aim was to gain an understanding of the lecturers' experiences, practices and views in accomplishing the aims of practical work in Biology education. The findings of the study showed that the lecturers experienced many constraints that prohibited them from involving students in different kinds of laboratory work. The lecturers considered these constraints to have a negative impact on the accomplishment of laboratory activities, and put greater emphasis on the lack of carrying out fieldwork. Cossa (2006) also found that experiments by the students or lecturers, demonstrations, and practical activities set to familiarise the students with the use of equipment and materials and to enable the students to acquire procedural skills were frequently conducted while those practical activities aiming at motivating students and involving them in problem-solving or discovery experiments and investigations were rarely conducted. Cossa (2006) concluded that frequent use of any type of practical activities was influenced by the subject orientation in terms of its content and time allocation for completion of the laboratory activities. She further noted that there was a need for lecturers to teach science through laboratory activities that were related to their aims.

2.11.4 Uses of low-cost materials in laboratory work

Tlala (2006) conducted a study on the use of low-cost materials in biology laboratories at under-resourced schools in Mpumalanga. The findings of the study revealed that the use of low-cost materials might contribute to meaningful learning and positive change in the students' attitudes towards practical work. Tlala (2006) also found that students did not fully comprehend the meaning of diffusion and osmosis. Students confused the two terms and showed a considerable misunderstanding in the direction in which particles are moving. She noted that the students did not understand the term 'selectively permeable membrane' and its association with osmosis. She further concluded that the use of low-cost material increased the students' level of learning in terms of the acquisition of knowledge and intellectual, procedural and investigation skills as well as the interest, curiosity and confidence of students.

Motloutsi and Dekkers (2003) conducted a study to evaluate a programme intended to introduce teachers of Natural Science to the use of low-cost materials at the University of the North in South Africa as well as to find out whether teachers were aware of the positive use of improvised materials in practical work.

The findings showed that although most new teachers were aware of low-cost materials, they indicated that they lacked expertise in improvisation. Those teachers towards the end of the programme indicated that they were aware of such improvised materials and were using them too. Motloutsi and Dekkers (2003) observed that beginner teachers seemed not to be engaged in improvisation and therefore were able to teach without experiments that would have required improvisation. On the other hand, although teachers at the end of the programme were aware of low-cost materials, they were unable to overcome the problem of the lack of laboratory equipment. This suggests that to be simply aware of something is not enough and it takes more to be able to use a given strategy in the teaching and learning environment.

2.11.5 Potential of practical work in teaching and learning science

In their study of students' perceptual difficulties with graphical presentations of arrow symbolism in biological diagrams, du Plessis, Anderson and Grayson (2003) indicated that students' difficulties were caused by the misleading and confusing presentation of the arrow symbolism in diagrams as well as by a lack of understanding of the purposes of the graphic devices and poor perceptual skills. They stated that misleading and confusing presentations could cause various difficulties in students' perceptions and may hinder the internalisation of new information in science education. However, they further claimed that well-constructed graphs could lead to the enhancement of the understanding of scientific concepts by students.

The findings of the study conducted by du Plessis et al. (2003) showed that diagrams do not contain enough visual support to help students understand what the pictures are supposed to represent. They suggested that visual literacy skills should allow students to be able to extract important educational information from pictorial illustrations. They reported the common difficulties that the students experienced as the following:

- Spatial organisation (layout) of the diagrams;
- Poor search patterns to group appropriate information together;
- One or more arrows in a pair or group of arrows are ignored;
- A local focus rather than a global focus limits the value of supporting cues;
- Relevant features or cues are not distinguished from other information; and
- The position of the arrow relative to supporting information is poorly identified.

Du Plessis et al. (2003) concluded that pictorials that teachers construct or help students to construct should facilitate rather than hinder their understanding of a given phenomenon. There is, therefore, the need for teachers to be sensitised on how to construct visual teaching aids in relation to diagrammatic representations and their use during instruction. They suggested that there is a need for students to learn these concepts, links, and what they need to look at when analysing an illustration. This is where classroom/ laboratory discourse becomes important within the social constructivist perspective as a learning theory. For example, an illustration is seen as one of the scientific tools, which is heavily loaded with information. Unless students learn alongside an expert they may not be able to understand these illustrations.

Du Plesis et al. (2003) also identified various types of illustrations that are used in biological science. These are drawings, graphs, speech illustrations, real images, and hierarchical illustrations. The importance of the symbolic representation is certainly worthy of closer consideration, especially when the focus is on practical work. Teachers need to be made aware of this problem and helped to take appropriate actions to provide guidance to students

Maboyi and Dekkers (2003) conducted a study to explore teachers' purpose for doing practical work in teaching Natural Science at the University of the North in South Africa. The findings indicated that almost all the respondents preferred teacher demonstrations because of the lack of financial support and the lack of laboratories and laboratory equipment as well as large classes. They also reported that the most common practical activities lecturers conducted focused on practical activities that were meant to demonstrate, identify, verify and prove selected concepts and principles. Furthermore, the findings indicated that teachers had different views on why they included practical work in their teaching. Most indicated that practical work is vital because it offers students the chance to manipulate equipment, and observe, interpret, record and draw conclusions. However, the use of practical work to support theory is a view that has been discredited in international studies (Woolnough & Allsop, 1985).

From the forgoing discussion, it is evident that biology teachers need to be aware of the mismatches that may exist between the implemented and the intended curriculum for the aims of practical work. Teachers need to understand the fundamental aims of practical work and the role they play in organising a range of practical activities to be aligned with their aims and purposes (Bekalo & Welford, 2000; Erduran, 2003). Biology teachers need to be sensitized to provide more opportunities for practical work in particular, biological investigations than consider practical work to be a means of making phenomena more real through practical experiences (Thompson, 1975). Those who teach Biology should be encouraged to create opportunities for the students to be engaged in to a critical thinking, evaluation of ideas and able to negotiate and reach a consensus about what they are doing in practical work (Ramorogo, 1998). Such discussions should include the considerations of the constructivist perspective of an active student. What is more, the learning environment needs to improve considerably if biology teachers and educators at the management level of running schools are not only aware of but also do something drastic in order to improve the conditions of school laboratories at the secondary school level (Cossa et al., 2005; Gunstone & White, 2000; Haambokoma, 2007). Biology teachers need be aware of the difficulties associated with the language of science including the use of semiotics such as diagrams, graphical information, the use of specimens and how these can impact students' construction of meanings. They should be encouraged to discuss students' prior knowledge and employ specialized practical activities in order to reconfigure the multiple alternative conceptions of the students (du Plesis, et al., 2003; Gunstone & White, 2000; Hewson & Hewson, 1983; 1988). However, there is a need to equip biology teachers through training with the ability to design lessons so that students are guided to construct the ideas that they want to teach. In other words, they should design lessons in such a way that students are provided with bottom-up learning process.

2.12 Summary

Chapter 2 presented different perspectives on constructivist teaching and learning in relation to laboratory / classroom teaching. The origin, chronological and social context of constructivist teaching and learning were addressed, highlighting the strengths and weaknesses of the perspective within the teaching and learning of science. The researcher holds the view that considers the following aspects within the constructivist perspective:

- Students are actively involved in acquiring new knowledge both in a personal and social manner;
- Learning is an active intellectual process which involves deconstruction and construction of meanings;
- Learning outcomes are influenced by the learning environment as well as the students' experiences;
- Meaning is negotiated within the learning environment which is considered as a social setting;
- Social interactions are seen as important signposts for students to negotiate meanings from what they are learning;
- The level of cognitive development is seen as a contributing factor in promoting formal operational thinking;
- Social tools, including language, are used by teachers to interact with their students in negotiating meanings;
- Practical activities are overburdened with a range of aims that sometimes

cannot be realistically met and are carried out very rapidly;

- A variety of teaching strategies can be applied in order to assist students in acquiring investigative and practical skills;
- Students are overloaded with information and they fail to perceive the learning signals easily; and
- Constraints on practical work are associated with the lack of equipment, the lack of time, the lack of qualified teachers and of safety precautions. Such constraints create problems for the teaching of practical work.

Despite the various investigations carried out on practical work, the results have remained inconclusive in the area of laboratory discourse analysis. More needs to be investigated about the construction of knowledge under the guidance of an expert. For example, when should the expert 'say what' or 'when to say' or even 'how to say it' to students in a constructivist class. It is with this background that the present study attempts to explore the practices and concerns of teachers about practical work in selected senior secondary schools in Namibia. The nature of the classroom/ laboratory conversations between the teacher and students as well as amongst the students when engaged in practical activities in Biology Education) was explored. Hence, the researcher has strong reasons for undertaking the study in the area of practical work and hopes that the findings of this study will provide additional insights in the area.

The next chapter discusses the methodology, procedures of data collection and analysis.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

This chapter provides a brief account of the research design and procedures employed to investigate the classroom/laboratory discourse in Biology classes in selected Namibian senior secondary schools. As stated in chapter 1 the main aim was to present the nature of classroom/ laboratory discourse on how students were assisted by teachers to acquire practical skills and abilities and to uncover the various constraints that could have contributed to teachers not providing the necessary assistance as expected in a constructivist classroom/ laboratory. The methods and procedures used to obtain and analyse the data are discussed in the next sections.

3.2 Research design and procedures

The purpose of the study was to explore the nature of practical work as practised by two Biology teachers and how their instructional practices influenced the learning process. It was, therefore, important for me to choose a research design which would allow me to collect the best information with regard to the defined problem.

3.2.1 Research design

The present study predominantly used a descriptive, in-depth qualitative design. The design allows me to explore the dynamic nature of the classroom/laboratory discourse between the teacher and the students. A descriptive, in-depth research study has been shown to provide the most amenable information when studying the quality of practices and views of the subjects (Denzin & Lincoln, 2001). In addition, Patton (1990) and Cohen et al. (2000) noted that qualitative research provides room for the researcher to go deeper in understanding the practices and feelings of the subjects with regard to the concepts under discussion. In a qualitative study, meanings of how subjects perceive and make sense of their practices and/or situations are prioritized in a meaningful way (Bell, 1993; Creswell, 1998; Gay, 1992; Vulliamy, 1990).

The study used case studies to explore the natural settings in a natural and holistic manner by interviewing the teachers and students, observing classrooms (Bell, 1993; Silverman, 2001). I used the school setting in order to identify the teaching and learning interactions, to record behaviours in their natural settings and to identify the contextual elements which may influence the cultural practices and lives of the teacher and students (McMillan & Schumacher, 1997; 2001). The study, therefore, construes the classroom as a natural setting. To achieve a comprehensive picture of practices in the Biology classrooms, this study attempted to fulfil the following requirements:

- Get close enough to the teacher and students and situations being studied to personally understand in-depth the details of what goes on;
- Aim at capturing what actually took place and what people actually said (perceived facts);
- Include a great deal of clear descriptions of people, activities, interactions, and settings;
- Include direct quotations from people, both what they spoke and what they wrote down (Patton, 1990, p. 32);
- It aims at observing classroom interactions in a natural setting (Creswell, 1998; Patton, 1990); and.
- Focus on interpreting classroom discourses especially at the teacher-student and student-student levels (Silverman, 2001).

Also the research draws inspiration from a social constructivist perspective (as described by Vygotsky, 1978) in which "knowledge is constructed through a process of self-conscious action by those who are personally experiencing it"

(Schurink, 1998, p. 247). My approach was, thus, 'idiographic' and used 'an emic perspective of inquiry' (Schurink, 1998, p. 242). In other words, this study sought to understand the meaning teachers attached to their daily instructional practices and perspectives. In the study, I explored the nature of practical work, in particular, the way in which the teachers provided apprenticeship as well as applied scientific tools to enhance the students' scientific understanding. The following research methods were used: (1) interviews with the teachers, (2) interviews with the students, (3) classroom observations (video-taped) and document analyses (lesson plans, students' class work books, and students' test books).

Research Design

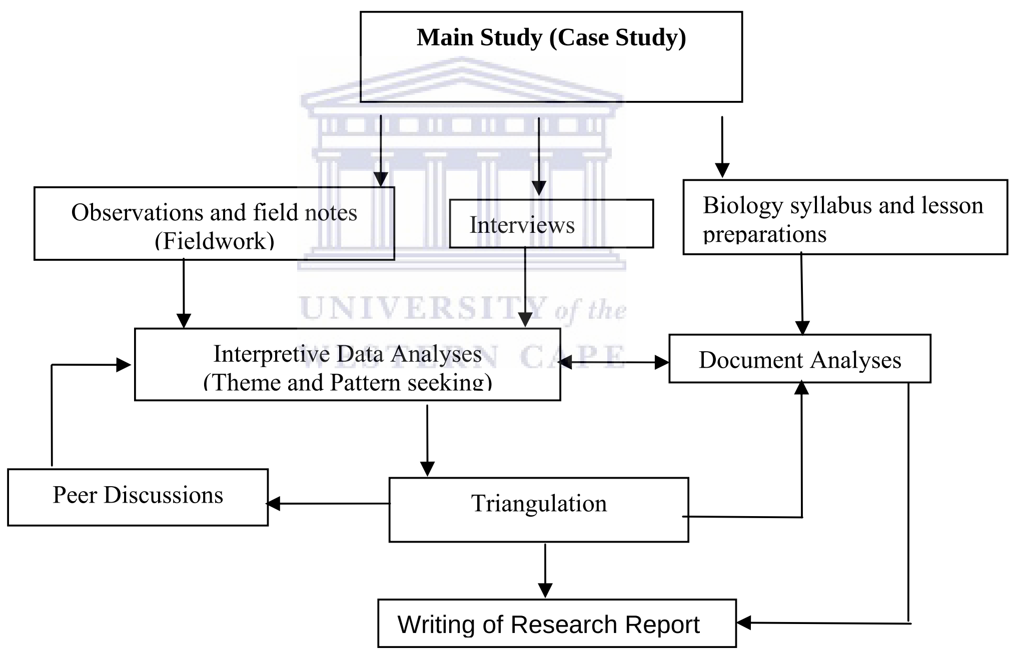


Figure 3.1: A Pictorial Representation of the Research Design.

3.2.1.1 Period of the study

The study was restricted to the second trimester (last week in May till 20th of August 2004 and 2005). Educational research is burdened with many unpredictable circumstances and some of these circumstances were:

- The timetables of the school sites where the study was conducted were not complete, particularly for the first week when schools re-opened.
- Teachers were involved in in-service training workshops and were not willing to participate in the study.
- The last month, August was mainly spent on internal examinations and teachers stopped teaching altogether.
- Practical work was only taught twice within seven days and in addition, a teacher could decide not to take students to the laboratory but to simply lecture.

A concerted effort was made, as far as possible, to gather sufficient data from which meaningful inferences were drawn. For example, I interviewed three students after practical sessions. Altogether 17 practical and 21 theoretical sessions were video-taped by the researcher. The teachers were interviewed five times on different occasions. In addition to this, I collected documents such as copies of students' class work, copies of students' practical books and lastly, I attended the practical examination session for one and half hour in order to have a feeling of how students were tested during the examination.

3.2.2 Sample of the study

The sample of the study consisted of three senior secondary school teachers teaching NSSC Biology to grade 11 students in Namibia at the time of data collection. However, this study was carried out in the Windhoek Educational Region and comprised only of two urban schools, located in two different socio-economic suburbs.

3.2.2.1 Sampling

A purposeful sampling approach was used to select the target groups, consisting of three grade 11 Biology teachers. Purposeful sampling was deemed necessary because I was interested in the depth and richness of the information (Creswell, 1998; Stake, 2000) from the subjects than an overview of many participants as well as the increase in the quality of information to be gathered (Bless & Higson-Smith, 2000; McMillan & Schumacher, 1997).

I, therefore, used a multi-stage sampling procedure; i.e. a procedure where I first sampled schools and then identified the potential teachers within each school (Creswell, 1998). In selecting the schools, I employed a site selection approach in order to locate the schools with promising subjects. Site selection sampling was found to be useful because of its focus on complex micro-processes such as teachers' decision-making in terms of learning activities, and strategies regarding classroom management as well as the performance of students in examinations (McMillan & Schumacher; 2001).

The sample size is relatively small (i.e. three experienced Biology teachers because the aim of the study was not to generalize the findings to a larger population but to understand the nature of classroom/laboratory practices in two senior secondary schools in Namibia). I described the possible sets of criteria that were used to select the settings that would seem logical to provide information to the questions under discussion. I used these descriptions as guidelines to purposefully select the sample of the study. The three Biology teachers were selected based on the following guidelines:

1. The teachers taught at a school with well or fairly established infra-structure, (that is, the school was well or fairly well equipped with laboratory materials);
2. The teachers had appropriate command of their subjects and had taught for three or more years at the same school;
3. The schools had a good record of students' performances (i.e. C and above symbol in Biology); and
4. The teachers were willing to participate in the study.

In addition, a group of grade 11 students from each classroom that was observed were also included in the sample in order to study the teacher-student interaction. Grade 11 teachers were preferred because their students were not involved in writing formal examinations at the end of the year. General constraints associated with examinations were thus reduced. Altogether 36 students were interviewed on several occasions and 15 practical lessons observed.

3.2.2.2 Limitations in the Procedure of sampling

As indicated above, the study was limited to only three volunteer biology teachers, though several expressed interest at the commencement of the study. As the study progressed some teachers for one reason or another dropped out. This dropout rate reached its peak during the fieldwork, and it was difficult to find substitutes. Had the sample been large enough, the researcher could have been in a better position to see the findings as applicable to a much broader context. In the absence of a large sample, it is difficult to determine to what extent the findings could prove useful or generalisable to other settings (Cohen, Manion & Marrison, 2000; McMillan & Schumacher, 2001).

Nevertheless, the aim of the study was not to generalise the findings to a larger population but to provide some glimpses into the type of instructional practices relating to practical work that might be taking place in senior secondary schools in Namibia. As the findings are brought into the attention of prospective and practising biology teachers and other stakeholders, it might be easier to get a larger cohort of teachers willing to take part in future studies in the area.

3.3 Schools and Teachers' profiles

In this section, I present the profiles of the schools and the teachers. The teachers who took part in the study were members of staff of the school and students who attended school at the school sites. Fictitious names were used to protect the identities of the teachers and students. In my views the vignettes and narratives of the teachers and students are potently educative and rich in information. Therefore, I used the vignettes and narratives to provide rich and deeper information about what happened in the schools as revealed by the voices of the students and teachers.

3.3.1 The Profiles of School A and B

In this subsection I present the profile of the different schools where the study was conducted. In the next subsection I focus on School A followed by School B.

3.3.1.1 School A

It is a high school which was established with the aim of educating German-speaking children during the colonial era. The school is situated in one of the former white suburbs, Lutwein, in the Windhoek Educational Region. The school is within reach of a shopping centre where the teachers could easily buy science equipment and materials. After the independence of Namibia in 1990, the school's population profile had changed tremendously and it started registering a number of black children.

A typical high school in Namibia consists of grades eight to twelve, that is, junior and senior secondary levels are combined in most high schools. It has a well developed infrastructure in terms of learning facilities such as the science laboratory, library, laboratory equipment, enough resource books and students' guides. The teachers are well trained academically and most of them have more than three years of teaching experience. In addition, the school has also a history of students who perform well in examinations at the grade 12 level. The Figure 1 below shows the biology laboratory.

This is the site of one of the laboratories at school A. The laboratory is well-equipped with a variety of equipment, modern gas and water taps at students' working stations.

Figure 3.2: Biology laboratory A at School A

In addition, there are different types of light microscopes and bi-viewers in the cupboards next to each working station. From the shelf on the wall, one can see the resource books as well as paraffin lamps and extra petri-dishes. Although the teacher was complaining about the overcrowded classroom, the laboratory was built in a modern way. The laboratory was only used for laboratory purposes and not for normal class teaching as was the case at other disadvantaged schools. Christie, a biology teacher at School A, was responsible for this laboratory and taught different grades over the years.

Jarijo, also a biology teacher at the School A, taught Biology to some grade 11 classes and most of the junior classes and she used the laboratory indicated in the next Figure 3.2. Although there were no students present in class, one can observe that the laboratory has the same setup as in the previous laboratory. There are at least water and gas taps and enough equipment to carry out practical activities and not just carry out demonstrations as is the case with other schools.

Figure 3.3: Biology laboratory B at School A.

At the back of the classroom, one can observe students' collections of insects and other organisms as well as posters. In the cupboards that are fixed on the walls, there are some illustrations of projects by students.

3.3.1.2 School B:

School B is a senior secondary school which was established with the aim of educating coloured children. School B is situated in a suburb, Riverside, where most people have an average life on the boundaries of the City of Windhoek within the Windhoek Educational Region. The school accommodates children from middle class families and is multi-ethnic. This school is well managed and has a good infrastructure in terms of buildings. The teachers are satisfactorily academically and are experienced teachers. In addition, the school has also a history of students who perform well with their grades ranging between A - C at grade 12 level.

At school B the laboratory setup is different. There are no fixed working stations for students as was the case at school A. There are only long benches with no gas or water taps. The laboratory is also used as a normal classroom for teaching Biology. However, there are small storerooms attached to the biology laboratory at School B. Lena, the biology teacher at School B, teaches practical work under these conditions.

Figure 3.4: Biology laboratory at School B

The next Figure 3.4 shows the inside of the store room of the Biology laboratory. One can see a number of pieces of equipment, materials, chemicals and two microscopes.

Figure 3.5: A storeroom for the Biology laboratory

3.3.2 Profiles of Teachers

In this subsection, I describe the profile of the teachers at the selected school sites. The profiles of the teachers enabled me to have a better knowledge about the experiences and instructional practices of the teachers at the two school sites.

3.3.2.1 Christie

When Christie was asked telephonically if she would be willing to participate in the study, she responded enthusiastically. Thereafter, I made arrangements to observe her practical classes during the second trimester. I observed the lessons over a period of three consecutive weeks. The focus of the practical work was to help the students develop a valid understanding of the processes involved in determining different types of food using various indicators. A related aim was to enhance the students' practical skills such as manipulation of apparatuses, mixing chemicals, observation, measurement, recording and analysing data, and reporting findings as accurately as possible.

Christie was 46 year old, a female Biology teacher and she speaks three languages: German, Afrikaans and English although all her instructions were conducted in English which is the medium of instruction in Namibian schools. Christie is a voluntary member of the school management who has a full teaching load, that is, teaching up to six periods a day for a seven-day cycle timetable. Her teaching load was approximately 42 periods a week in addition to her administrative work. She indicated that she focused on her administrative work during the afternoon. Christie had 23 years of teaching experience at the time of data gathering. She had taught Afrikaans and Accounting for one year and Biology and Life Science for more than 22 years. Christie studied zoology and botany as extra subjects and completed her four year education degree (BAEd) in SA. She did pedagogic subjects for three years but she does not have a HEd (higher education diploma).

3.3.2.2 Jarijo

I was introduced to Jarijo by the subject head of Biology, Christie. Christie was confident that Jarijo would be willing to participate in the study and I decided to contact her. Jarijo is a young female Biology teacher who was 27 years old. She had taught for three years and she was teaching Biology to grade 11 (one class group), Mathematics to grade eight and nine as well as Life Science to grade eight and nine. She speaks Afrikaans and English and her classes were taught in English too. Jarijo has Bachelor of Science degree where she has a double major in Biology, that is, environmental Biology and cell molecular Biology. However, she does not have a teaching qualification which is a requirement in order to teach in the Namibian education system. She is currently enrolled for a teaching diploma at the University of Namibia as a distance student.

She could be quite humorous and could really speak loudly to students while teaching. Sometimes she loses control as she screams at students to be silent. Although Jarijo has fewer years of teaching experience she indicated that she relied very much on her senior biology teachers to assist and guide her in terms of planning and teaching her students. Like Christie, Jarijo first focused on teaching the content before she could take her students to the laboratory.

In Namibia, the curriculum prescribed that there should only be two periods for practicals in two weeks. Sometimes this arrangement creates problems for both the teacher and the students when they cannot finish what they are doing in the laboratory in time as we will see in the discussion that follows in other sections.

3.3.2.3 Lena

I was introduced to Lena by the Headmaster of the school during the first semester. When I approached Lena, she was willing to participate in the study. Lena was the only female Biology teacher employed at school B and she was responsible for teaching Biology to grade 11 and 12 and Life Science from grade eight to nine. She was 32 years old and speaks Afrikaans and English. In compliance with the education policy, Lena taught her lessons in English and she was also a member of the school management as well as a Head of Department of the Natural Sciences. Natural Sciences consist of subjects such as Mathematics, Physical Science, Biology, Life Science and Agriculture.

She had nine years of teaching experience with five of these as the Head of Department. She started her teaching career as a physical science teacher (for two years) but later taught Biology and at the time of data collection Lena had seven years of experience in teaching Biology.

Lena had a Bachelor of Science degree in Botany and Zoology and she had a postgraduate education diploma in education. She indicated that she attended several training workshops and seminars on the new curriculum. In addition, she had also marked the end-of-year external examination at the grade 12 level. The examination papers for Biology are set and moderated by Cambridge University, although they are marked in Namibia by trained Biology teachers. Lena also said that she was involved in in-service teacher training programmes on several occasions.

I made arrangements to observe her practical classes during the second trimester. The timetable for the Biology subject consisted of eight periods per week of which two periods were for laboratory work. At school B, I observed Lena both during normal teaching periods as well as the practical periods on different occasions that lasted for 40 minutes a period. The topics that she focused on were nutrition in plants and food tests.

The purpose of the profiles was to provide some information about the participating teachers and the school environment where they worked. The information helped me have a fuller picture of the teaching-learning environment. In chapter four, I presented in greater detail the activities that took place in their classes and responses of the participating teachers and students in narrative form to questions posed to them during interviews.

3.4 Research Strategies

Case studies are qualitative research designs and focus on particular cases, (e.g., the context of the case such as the physical, social or historical/economic setting, Creswell, 1998; Merriam, 1988; Stake, 2000). By their nature, case studies attend to social situations such as the inconsistencies or conflicts between viewpoints which are held by subjects (Cohen et al., 2000).

To answer the research questions, a case study design adopted from the six-qualitative phases as described by McMillan and Schumacher (1997) was used as a framework. Essentially, the six phases are: (i) planning, (ii) beginning data collection, (iii) basic data collection, (iv) closing data collection, (v) completion of data collection and (vi) continuation of data analyses. Details of the six-research phases design are provided in the next section.

Table 3.1 Phases of Data Collection

	Phases	Descriptions
1	Phase One	Planning
2	Phase Two	Beginning data collection
3	Phase Three	Basic data collection
4	Phase Four	Closing data collection
5	Phase Five	Completion
6	Phase Six	Continuation of data analysis

3.4.1 Phase One Planning

During this phase, I analysed the research problems and possible research questions were generated to focus on the problem under discussion. The research questions were refined further in relation to the literature that was reviewed. It was also during this phase that I developed the preliminary interview and observation quoting schedules. The interview schedules were subjected to content and construct validity by three experienced Biology teachers and two university lecturers with experience in teaching Biology and laboratory work. The interview schedule was validated for readability, spelling and structuring of question order as well as for the appropriateness of the content and whether the items covered the objectives to be attained through practical work. The original interview schedule consisted of ten questions and the final schedule had five questions. I improved the interview schedule before interviewing the students for the main study. The final version of the interview schedules were completed after the first interviews.

The video observation quoting schedules (VOQS) were adopted from Millar et al. (1999) on laboratory work as well as from Mortimer and Scott (2000) on classroom discourse in terms of teaching practical skills. In the study, the flow of interactions focuses on three aspects of classroom discourse: the nature of teacher intervention, the form of teacher utterances and teacher actions in the flow of the discourse. The three aspects of classroom discourse are discussed next.

a) The nature of teacher intervention

This aspect of analysis was based on Mortimer and Scott (2000) which aims to characterize patterns in the flow of discourse in science content lessons and it was expanded to include some features of teacher intervention as described by Brooks and Brooks (1993) about constructivist classrooms. Six categories of teacher interventions have been identified: sharing ideas with the students, selecting ideas, shaping ideas, marking key ideas, checking students' understanding and reviewing scientific ideas.

b) Form of the utterances

This aspect of analysis focused on the form of students' and teachers' utterances. It involved three categories: description, explanation and opportunities made available. The description involved statements of what was directly observable or generally taken to be the case. The explanation involved explanations provided to make procedures and measurements clear, explaining to account for a specific event or phenomenon; and the nature of the opportunities provided to students to be involved in practical or experimental skills. The first two categories were based on Mortimer and Scott (2000) and the form of utterances was expanded to include the nature of opportunities made available to the students to exercise and develop procedural and experimental skills.

c) The actions in the flow of discourse

This aspect of analysis focused on the types of activities that were performed by the students and teachers during the practical sessions. It involves three categories: practical skills, demonstrating activities to students and the nature of the assistance provided to the students. Practical skills involved procedural and conceptual skills performed by the three teachers and their students during the practical sessions.

The Framework that were used to analyse the teachers' actions in the flow of discourse, the forms of teachers' utterances and the nature of the teachers' interventions were presented in Appendix P and the framework that were used to analyse the student-student interactions is presented in Appendix Q.

The VOQSs were used to analyze the transcribed video-taped classroom discourses in relation to the dialogue and the nature of teachers' intervention during practical work. Mortimer and Scott (2000) focused on the content of the discourse in relation to conceptual learning goals while the adapted version focused on the type of platform the teacher provided in order to negotiate and appropriate meanings through the social plane, that is, the utterances of the teachers and the students in relation to establishing meanings and the sharing of information in learning practical skills.

Secondly, the VOQS also allowed me to record the frequencies of specific interactions such as the activities of the teachers and students which focused mainly on developing practical skills. The quoting schedule was used mostly in analyzing video recordings for identified categories in the practical lessons.

Thirdly, the VOQSs were adapted in three different ways for the quoting schedules to be relevant to the Namibian situation. During the preliminary observation period, it became clear that practical work in Namibia was offered in four different ways and these needed to be reflected on the quoting schedules. Firstly, sometimes teachers offered practical work in a lecture-oriented way. The teacher provided the theory on how to carry out a certain laboratory activity without really engaging students in demonstrations, laboratory work or investigations. Secondly, teachers carried out demonstrations to the whole class. Sometimes this ritual was changed slightly when the teachers were assisted by a few of the students in order to carry out the demonstration. Thirdly, the teachers allowed their students to carry out experimental work in the laboratory in small groups of four to six students. Lastly, the students at some schools carried out projects but this did not take place at the time of data collection. Thus, the quoting schedules were adapted by me and two research peers to include (a) teacher-student interactions, and (b) student-student interactions which were relevant to the situations at the different research sites.

The quality of the instruments was established through the use of two research peer analysts. Consensus was reached amongst the identified categories according to the types of practical activities (a laboratory, demonstration, lecture and discussion lesson) amongst individual raters. A discussion was held in order to establish interrater reliability. The individual raters' reports were examined for any differences or additions and then differences were discussed and ironed out (Gay, 1992; Silverman, 1993; 2001). A high level of agreement was reached through discussions by the three peer researchers.

It was in phase one that I also gained permission from various school authorities; identified the documents for analyses; and networked with the subjects.

3.4.2 Phase Two: Data collection Phase

The Regional Director for the Windhoek Educational Region and the principals of those schools which were going to participate in the study were approached in order to obtain permission to carry out the study. I also sought permission from the teachers and the students who took part in the study. After that I arranged for an observational time-table with the respective teachers for classroom observations. The time-table helped me to adhere to the arranged schedule of appointments. I started visiting the research sites as early as possible in order to be familiar with the participants as well as with the physical environment of the sites. I spent a week at the identified schools in order to establish trust and reciprocal relations with the subjects who were observed and interviewed (McMillan & Schumacher, 2001).

I interviewed two students after the first observed lesson and this process enabled me to improve on the interviewing schedules. In addition to interviews, I observed a practical lesson and video-taped the session while in progress. The interviews and the videotaped lesson were transcribed verbatim and adjustments were made to the order and relevance of questions in relation to the main research questions.

I developed a meaningful strategy on how to organize the collected data during this phase. I started with preliminary data transcriptions of the two students who had been interviewed on audio-tape and classroom observation of the first observed lesson on a video-tape during this phase and started with preliminary sequential data analyses. In addition to improving the interview and the observation schedule, I decided to keep thick field notes about what was happening in the classroom which yielded rich data.

3.4.3 Phase Three: Basic data collection

I spent six weeks in the field visiting the identified schools to collect data. I drew up a timetable schedule in order to interview the identified subjects and to observe the classroom/laboratory practices of the selected practising Biology teachers.

3.4.3.1 Interviews

I used interviews as described in the previous sections. The interview schedules were used as a guide in carrying out individual interviews with the students and teachers. I specified the questions in advance before I visited the case sites. This allowed me to collect data in a comprehensive and systematic way from different subjects. As the interviews were semi-structured, they were flexible in relation to sequencing and wording (Gay, 2000; McMillan & Schumacher, 2001; Patton, 1990). The interviews were held with the Biology teachers as per appointments and were based on issues that took place during practical work instruction.

The subjects in all the interviews were informed that the interviews would be audio-recorded. Before the commencement of the interviews, they were reminded of the purpose of the interviews and the confidentiality of the information (Bell, 1993; Kvale, 1996; McMillan & Schumacher, 1997). A brief explanation was presented to the subjects in order to inform them on how the interview session would proceed (McMillan & Schumacher, 1997). Each interview session took approximately 5 - 10 minutes.

The recording of the interview sessions ensured the collection of a comprehensive report of the conceptions of the practical work of the subjects (McMillan & Schumacher, 2001). In order to reduce the researcher bias, the transcribed tape-recordings were given back to the subjects for further verification. They were also requested to go through the transcriptions and if they felt like adding more information they could do so. The majority of the transcripts came back with minor corrections most of the time. In addition, I kept an in-depth field notes to help reformulate the questions as well as probe and record the interactions which I considered relevant to the process of data analyses (McMillan & Schumacher, 2001).

Interim data analyses also began during this phase. The process of interim data analyses allowed me to process ideas and facts mentally while collecting and summarising the data (McMillan & Schumacher, 2001). The process of analysing the data provisionally provided room for me to refine the received interview information from the subjects.

3.4.3.1.1 Students' Interviews

Altogether 36 students were interviewed in face-to-face (Creswell, 1998; Kvale, 1996) interviews on several occasions. Three randomly selected subjects from each classroom observed, were interviewed before and after the practical sessions.

The interviews with students took place in the laboratory or a classroom on the school premises. The interviews were held during official school hours, (i.e. interviews were conducted during non-promotional school subjects and during the break time if the students agreed to the arrangement).

I believe that the interviews provided me with an in-depth understanding of the students' experience of laboratory activities. The follow-up interviews with the students focused on providing me with more insight into the possible conceptual changes that had occurred and also how the teachers provided mediations (although rarely provided) to help the students learn specific practical skills and abilities. In addition, the individual interviews with the students provided me with an opportunity to ask follow-up and probing questions for further discussion and clarification of ideas (Hall & Hall, 1996, p. 101). I also used semi-structured interviews that were open-ended. Students were given freedom to respond to questions in greater depth as well as to motivate their responses (Bell, 1993). The interview schedules used in the study are presented in Appendix C and D.

3.4.3.1.2 Teachers' Interview

The Biology teachers who participated in the study were approached individually to seek their willingness to participate in the study. The selected Biology teachers were interviewed individually several times.

The preliminary interview was conducted at the beginning of the study just before the classroom observation sessions started in order to get the necessary information about the running of practical work, the normal teaching load of the teachers at the schools as well as to develop an interview timetable for the interviews. A series of interviews was conducted between the first and the last practical sessions and focused on classroom discourse that took place during classroom and laboratory activities.

The information received from the students' interviews enriched my understanding of what happened in classrooms/ laboratory and guided me to what kind of questions I should include in the teachers' interviews. It was impossible for me to know beforehand what would happen during instruction or what important aspects would emerge (McMillan & Schumacher, 2001; Merriam, 1988). As a result, there were no preset questions or phrases for the teachers' preliminary interviews. However, I was aware that posing valuable questions and directing questions that would cover the research objectives would be rather challenging. The interview schedules used in the study are presented in Appendix E.

3.4.3.2 Observations

Observation is another useful tool that was applied in the collection of the data not only to cross-check what was reported in the interviews (Merriam, 1988) but also "to go beyond external behaviour to explore the internal states of the people who have been observed" (Patton, 1990, p. 245). In other words, observations permitted me to record both the teachers' and students' behaviours as they occurred during instructions. Utterances between the teachers and the students or between student and student as they interacted within the classroom social context provided a good example in this regard. The utterances between the teacher and the students were commonly used to explain, analyse diagrams, tables and graphs during practical work. Therefore, the classroom climate carries important meanings that should not be ignored within classroom discourse (Mortimer & Scott, 2000). Words and sentences provided sensitive information in relation to what human beings have experienced as well as their worldviews (Bell, 1993; Bless & Higson-Smith, 2000). Hence, speech genres, social language within the classroom setting and utterances provided essential information for the study and were used to analyse the nature of the classroom discourse.

The observation quoting schedule was used to record the frequencies of observed interactions on video-recordings. The schedule consisted of four parts:

- Part A - focused on the teacher's interactions and included the assistance given to the students, the descriptions and explanations provided to the students, the types of process skills applied during class work, and the nature of teacher interventions strategies used during instructions; and
- Part B – focused on student -student interactions during group experiments and included the types of process skills applied during class work, patterns of interactions, and the focus of discussion.

The environment in this case included the real materials/objects or projects and models produced by the students as well as laboratory apparatus while interactions such as planning and carrying out of practical investigations were considered.

In addition, learning outcomes (procedural or conceptual) provided important information in relation to the purposes of the practical activities. For example, it was appropriate to find out the degree to which the teacher used learning outcomes (procedural or conceptual) across the different aspects of practical work rather than becoming over-focused on only one particular domain. I made notes about the structure of the classroom discourse in relation to the types of roles the teachers played and the types of interventional strategies they used (Flick, 2000). These parameters are directly or indirectly related to practices of constructivist approaches and student-centred approaches in teaching science. The VOQSs are presented in Appendixes P and Q.

Notes were kept to describe interactions that took place during each practical session (Judd, Smith & Kidder, 1991) as well as to provide additional information on what happened during classroom observation immediately after the completion of each observed practical session while much was still remembered (Merriam, 1988). As a participant observer, I sat in the theoretical classroom sessions and video-recorded the proceedings too. In some cases, I helped the teachers in arranging the equipment before practical sessions. These sessions provided me with some skills. For example, I learnt to focus on a specific behaviour at a time (Gay, 1992; 2000) during classroom/laboratory activities when video recording class interactions were going on.

As indicated above, the study included video recordings of the classroom interactions between the teachers and the students during the practical sessions (Cohen & Manion, 1980; Patton, 1990). W. J. Schurink, E. M. Schrunk and Poggenpoel (1998) suggest that a videotape recording can be utilised as a way of recording directly occurring behaviour in a natural setting as well as avoiding some disadvantages, which are associated with interviews. Some of the major advantages of videotape recordings are:

- The data gathered through videotaping is more comprehensive and thicker in comparison to other techniques of data collection that can be preserved for successive analysis;
- The video recorded data set makes it possible to review events as often as needed, that is, behaviours recorded could be viewed and reviewed at will during data coding; and
- Trained assistant researchers can use the facility to record the teacher and students' utterances during classroom conversations if the fidelity of the system is good, that is, the fact that the video camera deals with

conventional classroom setting and microphones are able to pick up the greater proportions of the utterances that takes place in the classroom (Cohen & Manion, 1980; Schurink et al., 1998).

In order to fulfil ethical requirements, all the subjects were informed that the classroom interactions would be recorded by the methods of keeping notes as well as video and audiotape recordings and the devices were not concealed (Gay, 1992). The idea was to triangulate the video recordings sessions with the notes taken in order to establish the validity and reliability of the classroom/ laboratory observations (Schurink et al., 1998).

3.4.4 Phase Four: Closing data collection

The last few weeks were spent on finalising the interviews and making sure that I collected the necessary documents for document analyses. Copies of teaching notes, copies of students' practical manuals and teachers' preparation lessons were collected before I left the school sites.

3.4.5 Phase Five: Completion

As soon as I finalised active data collection process, I continued with the formal data analyses and the construction of meaningful ways of how to present the results. Conceptual themes were deduced from the main research questions.

3.4.6 Phase Six: Continuation of data analysis

3.4.6.1 Interviews' analyses

There are various methods and schemes to analyse qualitative data. Most methods are not well formulated and different researchers use different methods of approach to analyse qualitative data from different settings (McMillan & Schumacher, 2001; Punch, 1998; E. M. Schurink, 1998a; 1998b). However, whatever methods are employed, these need to be systematic, disciplined and transparent.

Creswell (1998) describes four forms of data analyses in case study research, namely, categorical aggregation, direct interpretation, establishing patterns and developing naturalistic generalisations. The categorical aggregation form of data analysis examines data for instances of relevant issues to the study. For example, in analysing the transcribed interviews, I examined the data for the instances that could be linked to practices of teachers during classroom instruction. In the direct interpretation form of data analysis, the focus is on a single instance or interview case. I sometimes drew meanings from a single interview without cross-checking with other interview cases. The above mentioned analyses scheme allowed me to "pull the data apart and then put them back together in a more meaningful way" (Creswell, 1998, p. 154).

Transcriptions were then analysed in relation to the types of practical activities used, views and feelings of teachers, practical skills developed through laboratory work, teaching strategies appropriate to develop practical skills, assistance provided to students and the degree of openness/closure of selected laboratory activities.

3.4.6.2 Video-taped and document data analyses

The data from the video-tapes were analysed in terms of the types of activities, teaching strategies, relevant patterns or characters from the dialogue between the teachers and their students (See appendixes P and Q). In addition, the above-mentioned data set was triangulated in order to reveal differences and similarities among the various categories. The term triangulation refers to a process involved in validating the data which were collected within a case as well as across cases. Triangulation of the data allowed me to explain more fully, "the richness and complexity of human behaviour by studying it from more than one standpoint" (Cohen et al., 1980, p. 208). However, this study only employed data and methodological triangulation (Patton, 1990; Stake, 2000) to provide answers to the research questions by using a variety of data sources: teachers, students, classroom observation (W. J. Schurink, 1998) as well as to analyse some documents (E. M. Schurink, 1998a).

3.4.6.3 Document analyses

Although documents are not interactive qualitative data, they are written text and/or images which provide linguistic information that are associated with events, people and actions studied (Silverman, 1993; 2001). The documents that were analysed in this study involved the NSSC-H and NSSC-O Level Biology syllabus, the transcribed interview conversations, lesson plans and students' workbooks. The documents provided other relevant information which was used to enrich the field observations and to provide background information for the real data analysis (McMillan & Schumacher, 2001; Merriam & Associates, 2002; Schurink et al., 1998; Silverman, 2001). The above mentioned documents were used to explore the value of students' work as well as the extent to which practical work was compatible with the assessment requirements (Gott & Duggan, 2002; McMillan & Schumacher, 2001).

3.5 The nature of the study

This report focuses on three volunteer grade 11 biology teachers and their students. However, it is necessary to mention that in reality, and for the sake of continuity, the teachers actually started to prepare their students as early as grade eight. Hence, to provide a broader view about the teachers' instructional practices would have necessitated a longitudinal study covering the three years. This perhaps would have provided a more comprehensive and deeper understanding of the teachers' instructional practices and beliefs about practical work.

The interviews were conducted in English - a language in which the teachers and the students were not so fluent. The reason for this anomaly is not hard to find when it is realised that Namibia as a political entity was once a German colony with German as the language of instruction. Later, Namibia became a mandated territory of South Africa and therefore Afrikaans became the language of instruction. At independence in 1990, the new government enacted a policy making English the official language for business and education. To compound the matter further is the fact that the Namibian territory is constituted of several ethnic groups with distinct languages. In such circumstances it should be obvious why the language of instruction constitutes a major barrier for both teachers and the students. I personally appreciate this matter because of the struggles I also have in understanding issues written in formal English. Often I lack the appropriate vocabulary to express myself in English. Sometimes this entails navigating across three languages- my own language which is Otjiherero, Afrikaans and finally English. Despite these limitations, however, I made concerted efforts to simplify as much as possible the language of instruction and the instruments that I used to attain as much responses as possible from the subjects.

3.6 Strengths and limitations of the methods used for data collection

The following limitations of the research methods were identified:

- I conducted the fieldwork and made sure that I caught unique features which were in line with the research questions. In other words, there were no research assistants to train during this period;
- All classroom/laboratory lessons observed were video-recorded and this allowed me to replay the lessons several times for careful analyses of data at a convenient time;
- It was difficult to get volunteering subjects even if permission was granted from the Ministry of Education and the Headmaster. Subjects could refuse to be interviewed and observed. I experienced this problem mainly with the teachers;
- Timetabling was another problem. Teachers sometimes did not stick to the timetable we agreed on. Teachers changed the timetable to suit their teaching loads and did not stick to the double periods for laboratory work.

Because different research sites were engaged, the running around between the schools became unbearable. I couldn't observe all the lessons as planned;

- The practical lessons that were arranged for the trimester were not all covered. Much of the time was taken up by normal class teaching;
- The video observation quoting schedules were only finalised after the first observation lessons were conducted. These might not fully reflect the teaching and learning environments; and
- It was difficult to transcribe interviews on time and give them back to the subjects for verification. Most of the time the transcribed scripts were returned with minor or no corrections, particularly, the transcripts of the students.

3.7 Credibility and Trustworthiness

As discussed earlier, this study lies within the qualitative research design. Unlike quantitative research that avails itself to internal and external validity and reliability, to measure the extent to which instruments are valid and reliable, the quality of qualitative data are addressed through "honesty, depth, richness and scope of the data achieved, the participant approach, the extent of triangulation and the disinterestedness or objectivity of the researcher" (Cohen et al., 2000, p. 105). It is argued that the meaning which subjects attach to data has more power than validity which is attached to data and methods. It is, thus, the richness and the agreement with subjects that counts more and it was against this background that the study construes descriptive validity (Cohen et al., 2000).

Descriptive validity refers to factual accuracy of the account. In other words, the data set was not made up, selective or distorted. When taking field notes, I ensured that the notes on the setting observed provided broad, detailed descriptions of what really happened during classroom settings. Interviews were transcribed verbatim and the subjects were given a chance to verify that the information they had given was expressed the way they wanted it. I also crosschecked available information from transcribed interviews and classroom observations with field notes in order to make sure that what was reported was done in a consistent manner. In order to cater for descriptive validity, I provided rich and in-depth field notes. Also interviews were conducted with the subjects in order to have a clear and a broad understanding of the meanings that the subjects attached to their actions and behaviours. Further, I verified the transcribed data by going back to the field several times to cross-check my interpretations with the subjects through discussions. Trustworthiness was increased by revisiting the settings several times and by cross-checking the interpretations of data with the subjects (Creswell, 1998).

Theoretical validity refers to the conceptual framework used by a researcher in order to explain the phenomena or events in terms of what all the participants have done. In this regard, I explained particular constructed issues within the observed settings with reference to accepted theoretical frameworks as explained within the constructivist perspective. Unlike experimental research that attempts to generalize the findings of a small sample to a population, generalisability in interpretive studies is left to the reader to generalise when the reported information is in line with what the reader is researching on (Silverman, 2001).

In order to establish qualitative internal validity, I made sure that the research design was sound. I am confident that the data collected had been recorded honestly and that the interviews conducted with the subjects for data confirmability (Cohen et al., 2000) had also been carried out with utmost care and a sense of responsibility.

In this study, dependability involved the use of member checks (interrater validation) and debriefing by research peers. Unlike reliability in quantitative methodologies where a procedure produces similar results under constant conditions on all occasions (Bell, 1993, p. 64), reliability in qualitative research (dependability) includes: “fidelity to real life, context-specific, situation-specific, authenticity, comprehensiveness, detail, honesty, depth of response and meaningfulness to the subjects" (Cohen et al., 2000, p. 120). In other words, one may ask the question about the consistency or dependability of an action or behaviour in describing what one is supposed to describe (Silverman, 2001).

3.8 Ethical issues

Ethics refers to a code of conduct in order to protect an individual's privacy. No researcher has the right to invade the privacy of the subjects involved in his/her study (Christian, 2000; Stake, 2000). In general, the code of ethics attempts to protect people's identities and those of the research locations. In the study, permission was sought from all the subjects. They were made to understand that they were free to stop participating if they felt in any way offended or uncomfortable in continuing with the study. Hence, all the subjects of this study were treated anonymously.

3.9 Summary

This chapter deals the research methodology as well as the specific research strategies which were employed to collect qualitative data. In chapter 4, the results obtained in relation to the research questions of the study are presented and discussed.

Chapter Four

Results and Discussion

> The teacher is undoubtedly the key factor in realising the potential of the laboratory. In order to be able to accomplish this mission, teachers need to be aware of the goals, potential, merits and difficulties of the school laboratory (Tamir, 1991, p. 20).

4.1 Introduction

One of the aims of the study was to determine the nature of interactions which took place in the biology laboratories of two secondary schools in Namibia. This entailed an examination of the types of tasks that were performed by the teachers and students on the one hand and the discourses that accompanied such activities on the other. This chapter presents a systematic and narrative account of the findings that emerged from the study. It also highlights interesting issues in form of interpretive commentaries and brief discussions. The narrative is about three biology teachers and their students in the two schools in question. The data from which the narrative was based were derived from various sources such as the interviews of the three teachers and their students, the direct observations of verbal and non-verbal interactions in practical and/or demonstration sessions, handouts, the Biology syllabus, practical manuals, and field notes.

The study adopted a two-fold approach suggested by Creswell (1998) namely, a critical and systematic analysis of some data collected at the two school sites and then reflecting on such data. Creswell's (1998) used an inductive approach to analyse data so as to search for "general statements about patterns among the categories" (de Vos, 2005, p. 340). Further, the approach entailed moving in analytic circles through the raw data several times and in the process producing ideas, short phrases, words and concepts or "memos" (de Vos, 2005, p. 343) about the biology teachers' perceptions of practical work on the one hand and the kind of practical activities they engaged their students in on the other. In other words, I revised the data in a cyclical and spiral manner (Cohen et al., 2000; de Vos, 2005) in the light of procedures and strategies used. Such revisions produced new data that were again subjected to new analyses. The cyclical process also allowed me to collect rich data and hence present a sort of thick, rich descriptions of the findings in order to generate in the socio-constructive sense, rich shared meanings of the reality extant in the biology laboratories and/or demonstrations in question. This analytic approach as de Vos (2005, p. 344) puts it:

> Demands a heightened awareness of the data, a focused attention on those data and openness to the subtle, tacit undercurrents of social life. Identifying salient themes, recurring ideas or language and patterns of belief that link people and settings together is the most intellectually challenging phase of data analysis and one that can integrate the entire endeavour.

In analysing the data, I focused on the types of practical activities linked to different practical aims such as: (i) to develop practical skills and techniques; (ii) to provide opportunities for students to solve problems as scientists do; and (iii) to get a feel for the phenomenon. I looked at how the given practical activities are linked to the different aims of practical work described in the NSSC H-Level Biology syllabus. Details about how the biology teachers attempted to achieve these aims are presented later in the chapter.

For ease of reference, the chapter revolves around three research questions which have been used as springboards for the analyses of the data. In the following section, I have made attempts to address the three research questions involved in the study beginning with the first one.

4.2 What practical activities do Namibian Biology teachers use to develop process skills (i.e. investigative and procedural skills) among their students?

To provide answers to the question above, I organised the data into three subsections of analysis. In the first subsection, I organised the data according to individual cases of the three biology teachers' perceptions of biology practical work. Each case focuses on the analyses and interpretations of individual case. The second subsection is concerned with the analyses and interpretation of documentary data about practical work. Documentary data were derived from the students' practical workbooks and manuals as well as the NSSC H- and O-Level Biology syllabus. The last subsection focuses on the analyses and interpretations of the students' perceptions of biology practical activities organized by their teachers. The teachers' profiles have already been discussed in detail in Chapter 3 and are not repeated in this chapter except to highlight how such profiles impacted on their instructional practices.

4.2.1 Analyses of individual biology teachers' perceptions of practical work

This subsection focuses on the analysis and discussions of the case data collected from the three biology teachers through observations and interviews. At School A, two biology teachers fictitiously named Christie and Jarijo participated in the study. Likewise Lena in School B participated in the study. Christie and Jarijo exposed their students to biology practical work in small groups while Lena conducted teacher demonstrations regularly. The section that follows would reveal how the teachers' profiles and underlying beliefs informed their instructional practices.

4.2.1.1 Christie

At the time of data gathering, Christie had been teaching for well over 20 years. The longevity of her teaching experience as well as teaching in the same school for many years had put her in an advantaged position in dealing with practical work in her field compared to a novice teacher. The biology laboratory and the normal classroom where Christie taught the theory are adjacent to each other. The former has an amphitheatre designed in such a way that Christie's working station is fixed in front while her students' desks were arranged in an ascending order away from her working station. However, the laboratory has a different setup. Christie's desk was fixed on a raised platform in front of classroom while the students' laboratory benches were arranged in five rows with typical laboratory stools. When standing at her working station, Christie could see with a bird's eye view what was happening in the laboratory.

Christie's students were organized into small but unequal groups in the laboratory. Some of the groups were big (i.e. consisting of up to eight students) while others had only four students. The students sat in groups with their friends or with peers whom they could easily work with. Some of the groups seemed to have been arranged in line with the preferred language of communication such as English, Afrikaans or German. However, now and then I could hear the students communicating in local languages such as Oshiwambo and Otjiherero. Most of the discussions in the small groups took place in these mentioned languages rather than in English which is the medium of instruction in Namibia.

When I entered the laboratory I found the students projects displayed in rows on the benches next to the windows. The photos of some of these projects that I took are presented in the later sections of this chapter. A detailed description of the laboratory where Christie organized practical work had already been described in Chapter 3 and hence is not repeated here. Rather the focus here is on what actually occurred while the lessons and practical work were in progress.

Christie's students were highly disciplined and hardly came late to class. They entered the laboratory and started working on practical tasks specified in the laboratory manuals that were assigned to them. Also, the students went to the laboratory only after Christie has presented lectures on the theory under discussion. There were no separate classes arranged for pre-practical discussions but these were conducted alongside the theoretical lessons.

At the time of data collection, Christie organized a range of practical activities that focused on food test (including testing for starch in various leaves). Many students enjoyed the laboratory activities and tried hard to complete their worksheets before leaving the laboratory. In most of the sessions I observed, Christie's role was largely laboratory management and safety. She also distributed needed materials or apparatus to the groups as well as provided assistance where necessary. Christie moved from group to group warning the students to take care of the gas taps and the flames of the Bunsen Burners. Most of the time, Christie operated at the background facilitating her students' endeavours through thought-provoking questions or by providing hints when necessary. In addition, Christie encouraged discussions on the critical issues after a series of practical tasks had been performed.

After observing Christie's lessons for few days I arranged an interview session with her in order to obtain additional information about her perception of practical work. The following questions are representative:

- What comes to your mind when you hear the word "practical work"?
- What types of practical work do you like to involve your students in most of the time?
- How do you prepare your students for practical work?

a) Christie's perception of practical work

The issue that often arises is that most teachers think of practical work only in terms of any activity that takes place in the laboratory. However, the nature and content of many of what teachers consider as being laboratory experiments are really not experiments as such but simple illustrations of phenomena, exercises or routines for students to follow instructions in order to acquire procedural skills (Donnelly, 1998; Gott & Duggan, 1995; Millar & Driver, 1987). However, Christie's thoughts about practical work (summed up in the following excerpt), reveal a broader meaning of practical work:

> To me as I have said means different things. It depends on the activities. We give them different things to do. Is only that we spread it over the years. Children come here without knowing what a microscope is or some have just heard about it. So all those different things, is not only grade 11 and 12 but also grade eight to ten. Some do projects and sometimes we take school trips to Swakop for them to see sea animals or to Etosha. In grade 11 and 12 we do not have time to do all those things. They do these things in previous years. But in grade 11 we do laboratory work than going out.

As an experienced teacher with more than 20 years of teaching, Christie's construal of practical work accords with the views of many scholars (Bekalo & Welford, 2000; Brown, 1995; McCarthy, 2005; Millar et al., 1999; Woolnough, 1994). Her ideas of practical work could also be observed in the way she organised and taught practical work in the school. As the head of the Biology and Life Science unit at the school, Christie had definitely a lot of input on how School A organised the teaching of practical work starting from grade 8 to 12. Practical activities in the school were spread over the years in order to allow the students to acquire the intended learning outcomes for practical work. In the next subsection a variety of practical activities are described as an illustration of what happened in Christie's laboratory sessions.

b) Types of practical activities organized by Christie in School A

As alluded to in the previous chapter, School A had developed a kind of a policy that allowed biology teachers to expose their students to a variety of practical activities. As part of the school's policy and as an experienced biology teacher, Christie was involved in initiating practical work for grades 8 to 12. She explained briefly and proudly as follows:

> We (biology teachers) give them a very basic something to do in the lab. And we are trying to teach them the basic apparatus and the names and the use. So that they know what is a Bunsen burner and how do you light it, things like that, but then on a very basic level.

The excerpt above was much reflected in the way grade 11 students conducted themselves in the laboratory sessions that I observed. The students appeared to be very much disciplined and carried out their tasks in an organized manner. Further, the students seemed to know what to do and did not wait for Christie to read instructions to them. Christie stressed the need for the students to start early in preparing for practical work. She further indicated that they tried to involve the students in a variety of practical activities and science projects right from grade eight to twelve. Her main concern was to provide opportunities for the students to acquire basic skills before they are introduced to complex skills. She saw such basic skills such as knowing how to use apparatus and materials as important stepping stones for developing higher-order process skills needed to conduct experiments that warrant the application of more complex practical skills.

Another important aspect that became clear from our interview sessions was that of using improvised materials and equipment. Some of the activities have multiple of aims to acquire procedural and conceptual skills. The students did not only attain procedural skills on how to produce a measuring cylinder for instance, but also how to produce other improvised materials which they could find useful in later years. Christie gave practical activities to her students in order to develop basic procedural and conceptual skills, for example, she said:

> Every year, we (Biology and Life Science teachers) do a little bit more. Well, in the beginning what I do for the first time, I have a lot of plastic bags, cool drink bottles. We cut the bottles, and I get the little plastic beakers with water, say a 100 mm and throw it in the bottle and then I have to make line where there is a 100, another 100, another 100. So they make their own measuring cylinder from these cool drink bottles. As it can't break, you know measuring cylinder is expensive and grades eights are still playful. They have to get use to doing

> things. And the top part of the bottle that we cut off, we use it for the funnel, so that they can get it in. It is useful.

From the above excerpt, it seems that students in Christie's class were also exposed to using microscopes in lower grades for a specific reason. Christie considered students ability to use microscopes in the lower grades as critical to their success in biology practical work in grades 11 and 12. She believed that it would be extremely difficult for the students to acquire all the skills needed for the 'Practical Test' or the 'Alternative to Practical' examinations in grade 12 if they had not been exposed to such skills at the lower grades. Responding to my reflective questions during the interviews about how she usually introduced her students to the use of the microscopes in the biology laboratory, Christie stated the following:

> For example, the microscopes work, of course. You have to have the kids in there with the microscopes and show them step by step, which the parts are, how to do these because we have different types of microscopes here. And then I will take them that everybody gets a chance to work with every one of those microscopes.

I also noticed that there were three different types of microscopes in the biology laboratory such as bi-piece light microscopes (using electricity), dissecting microscopes and simple light microscopes with a single eye piece (using light energy only). The microscopes were packed neatly and locked in cupboards just below each laboratory bench. There were also enough by-piece microscopes for all students. As indicated earlier, School A had enough laboratory equipment and materials. The school also seemed to have an effective way of managing the apparatuses and equipment in the laboratory as a whole. At the time of data collection, some students complained about the smell of gas. This made the school manager to seek for external assistance to investigate and fix all the gas pipes leading into the laboratories.

Responding to my questions, Christie informed me about what she had done with the grade tens in the previous years to equip students with investigative skills. She also indicated that sometimes she let her students use local materials to carry out investigations as well as to produce improvised equipment that students used in the laboratory:

> For example, in grade ten they [students] did projects on pollution as part of what they have to do in the syllabus. They [students] could still do investigations to find out what pollute water in their area or other types of pollution. Last year, we have a project and I sent them to pick the cigarettes boxes on the school yard and chips packages. They could still see few things we collected and then try to find out how much the pollution was. Last year we did the investigations and this year we did the models. One doesn't always want to give the same project. It gets boring for the kids as well.

Christie also indicated that she did different practical activities with students at different grade levels. From the excerpt above, one can deduce that she seemed to vary the projects from one year to another to enhance students' interests. Her students also carried out projects at different levels of difficulties such as: collecting samples of organs of indigenous trees (roots, leaves, pods and flower-parts); small-scale studies on leukaemia and investigating the causes of other human diseases. In general, projects or investigations of this nature tend to allow students to use and deploy necessary process skills in completing their tasks (Gott & Duggan, 1995; Woolnough, 2000; Wu & Hsieh, 2006; Wu & Krajcik, 2005).

The excerpt above further suggests that students were indeed involved in the investigations that centred on relevant issues which so to speak, were manifested in their communities. Also, lots of models of the heart, kidneys, skin, reproductive organs, lungs, the eye, embryo, teeth, tongue, liver, etc. produced by the students from grades 8 to 12 were on display in the labs. According to Christie these models represented only a sample of what her students had presented to their peers at one time or the other. Figure 4.1 below is representative of such models on display in the biology laboratory:

Figure 4.1 Samples of grade 10 students' models of different organs

While I was sitting in the biology laboratory waiting for the students, I could not help myself listening to one of the grade twelve students talking about the various projects undertaken by her classmates including the difficulties they encountered while producing the projects on display. She further mentioned how they tried to keep their models in shape at the time of production. There is a lot of literature support about the merits of investigations in terms of enabling students not only to plan and carry out given tasks but also affording them the opportunity to have direct experience with natural phenomena (e.g. Bekalo & Welford, 2000; Gott & Duggan, 1995; Woolnough, 2000; Wu & Hsieh, 2006; Wu & Krajcik, 2005).
Parkinson (1994) and Wu and Krajcik (2005) posit that the direct experience students have during investigations tend to equip them with necessary procedural and practical reasoning skills in evaluating and taking decision about whether or not to repeat certain steps as well as to question their own understanding. Millar et al. (1999) observed that the students do not only learn how to produce models but also how to communicate verbally to others on how they produced such models. In other words, they not only gained procedural or investigative skills prescribed in the NSSC H- and O-Level Biology syllabus, they also learned how to present or communicate to others what they had done (Liang & Gabel, 2005; Oh, 2005; Shepardson & Britch, 2006; Warwick et al., 2003).

Another aspect of practical work that I need to mention here is the teacher demonstrations. In all the sessions I observed, no biology teacher in School A had a teacher demonstration lesson. As explained earlier, students were involved only in carrying out practical activities in small groups. When I asked Christie why she did not use teacher demonstrations, she responded as follows:

> We seldom do demonstrations. I prefer the kids doing it themselves. But certain things if we have to dissect the heart, we don't have always enough. And those you get from the other classes are almost cut off. You can't see all the veins and stuff. So when we get one or two from the farm then I do a demonstration.

The excerpt above suggests that Christie only considered teacher demonstration when materials were scarce. With few exceptions, she seemed not be pressurised by lack of equipment or materials as is commonly the case in many other formerly disadvantaged urban and rural schools in Namibia and many other countries (e.g. Naidoo, 1998; Ogunniyi, 1986; 1995; 1996; Onwu, 1998).

I was interested to know why Christie engaged her students in group work despite the fact that some of the ones I interviewed seemed not to cope well in working alongside others. Some of the students seemed to dominate the discussions while others sat chatting on social matters than involve themselves in the practical activities at hand. Also, some of the students seemed to be frustrated by those who seemed not to like the idea of sharing equipment with others. Responding to my question on why she liked students to work in small groups, Christie stated that:

> I don't like it. If I have the opportunity, I will never let them work in groups so that they can always do the things themselves. But as you saw the labs spaces is a problem. The other thing is, time is a problem and if all 80 students have to do all the practicals, two years by themselves, we would use a lot of material, lot chemicals, lot of gas, lot of distilled water, which is expensive and we have to pay from our own school funds. So, the economic side is, you know, is tight. It is much cheaper doing it in groups.

What worried Christie most, perhaps, were the cost implications doing individual experiments. She was actually forced to practise small group instruction in practical work in order to save money and time. At times drastic measures were taken in order to compromise on the benefits that students would have had if they had worked individually. This means that Christie wanted practical work to be carried out by individual students but the financial situation could not allow her to teach practical work the way she wanted or the way that could have been more effective. Levitt (2002) also agrees with Christie that sometimes a teacher's instructional practice depends on both his/her belief and knowledge. Levitt (2002) contends that beliefs might sometimes be a stronger predictor of behaviour than other pedagogical considerations when a teacher implements a task. However, in the excerpt above, Christie's instructional practice seems to be controlled by the financial context rather than her beliefs and knowledge. However, Christie also was aware that collaborative work could also be beneficial to students. According to her, "Students do learn from one another, discuss things and take decisions amongst themselves. For example, yes, this is the way it should be or … Yah that's that happens here." It is worth pointing out that the extant literature is inconclusive about the benefits derivable from individual experiments on the one hand and demonstrations on the other. What seemed to count most are the context and the goal in question (Ogunniyi, 1986; Ogunniyi & Mikalsen, 2004; Ogunniyi & Taale, 2004). As pointed out in Chapter 2, each method has its merits and limitations.

An important type of practical work is scientific investigation. Investigations offer opportunities for students to acquire cognitive skills such as reflecting, interpreting, generating ideas, and evaluating procedures, planning and deducing (Hudson, 1994; Wellington, 2000). There was a certain norm practised in School A in order to provide investigative activities to students. This relates to the issue of whether or not Christie provided sufficient opportunities for investigations. Her view was that investigations could only be conducted on certain topics which were a part of the Life Science syllabus for grade ten. That means that the present grade 11 that I observed, had already conducted investigations in the form of projects in grade ten. Christie, for example, said that:

> Yes, in grade ten … pollution is part of the syllabus. They do investigations to find out what the water pollution in the area or other types of pollution. Last year, we have a project and I sent them to pick the cigarettes boxes on the school yard and chips packages. From the type they collected they could still see few things and you know they tried to find out how much, where the pollution was high, etc.

However, at the time of the data collection, I did not observe any practical session or projects specifically devoted to equipping students with investigative skills. She added that they do investigations every year with the grade tens. Each year they have different kinds of investigations with the grade tens. Christie further indicated that the grades 11 and 12 syllabus is compact and overloaded and that time was not on their side to do lengthy investigations or activities that would distract them from finishing the biology syllabus. This again is a vivid example of what Ogunniyi (1995; 1996) describes as examination maintaining a stranglehold effect on the education system. Despite this, Christie was aware of the importance of investigations as a means of helping students to develop essential basic and higher-order process skills that they would need somewhere else (Gilbert, 2003; Norris, 1992; Ogunniyi & Mikalsen, 2004; Wu & Krajcik, 2005). The models of organs that were shown in Figure 4.1 are illustrations of the types of project that the students produced.

In short, though Christie provided some opportunities for her students to acquire various procedural and conceptual skills, she was also concerned with the constraining circumstances surrounding her work in terms of the pressure of an examination driven curriculum as well as the insufficient time and space to organize investigative projects. It also apposite to point out that Christie had put in place a system that introduced her students to a variety of biology practical skills. Such an induction could introduce students into new concepts, ideas, understandings and theories and these in turn are likely enhance their ability to performance assigned cognitive tasks than would otherwise have been the case

(Hodson, 1996b). However, she was equally aware of the need to spread such practical activities in such a way that would enable them to develop critical process skills in a gradual and systematic way rather than expect them to be able to demonstrate such skills within a period of two years.

c) Preparation of students (both NSSC H- and Ordinary level) for practical work

The preparation of students for practical work in School A was spread over the years beginning from grade eight. Christie indicated further that she showed students all the equipment in the biology lab and allowed them to get accustomed to such equipment before starting any serious practical activities. Despite their relatively low familiarity with the equipment and materials at the junior secondary school level most of the grade 11 students that I observed seemed to enjoy the introductory practical work sessions.

Once the students were familiar with the biology laboratory, then, they were introduced to some basic practical activities. During the introductory sessions the students were taught names of basic apparatuses and chemicals as well as how to use them. Responding to my reflective questions about how Christie prepared the students and disciplined them for practical work, she said:

> Every year, we do a little bit more. So by the time they are in grade 11, they are familiar with the labs. That saves a lot of time when they come to grade 11 because we don't have to inform them on how and on what to do. They know where to start each lesson.

The excerpt above summarises quite succinctly what took place among the grade 11 students that I observed at the time of data collection. According to Christie, students were difficult to discipline and sometimes came to class unprepared. When Christie found out that certain students were not well prepared for the practical session, she usually disciplined them right on the spot (e.g. by withdrawing her assistance from them). During one of the practical sessions a student asked a simple question, 'How much of this solution should I add to test tube?', while another asked, 'Do I have to heat the solution?' Christie disciplined them by not providing the answers. Instead, she instructed them to read the practical manual. This is because what they were asking for was clearly explained in their laboratory manuals.

Some students seemed to read less and had to rely on their friends to tell them what to do. In some cases, I saw students looking at what other groups were doing instead of first reading their manuals and then commencing on their tasks after having understood what they had read. Christie indicated that reading and being prepared for practical work was one of the problems she encountered particularly with grade 11 students. She said:

> For example, the kids have a boiling tube explained in their summary and they have to add certain new solutions in there. And some kids didn't know what a boiling tube was. So, they put on their water bath and they put the solution in the test tube into the hot water. Then I ask them … 'are you sure? 'Did you read?' They usually say… 'yes boiling'. And that is all they read. And then I pointed out to them that they have forgotten what they want to say. Yah, definitely it is disastrous if they don't read.

Reading is a part of the learning process that should be seriously taken into consideration in the performance of practical tasks. Reading problems have been frequently alluded to in the examiners' reports on paper 3 dealing with "Practical and Applied Practical Skills (MEC, Directorate of National Examinations and Assessment, 2007). Poor reading skills or guessing may lead to other problems such as misinterpretation of questions, poor understanding of scientific terminologies and not following laboratory procedures carefully. Similarly, Jones (2000) maintains that reading in science should be reflective, and requires students to re-read and consider what they are reading. Parkinson (2002) also agrees with Jones (2000) that there is a need to increase the number of reading exercises in science lessons in order to improve students' literacy.

In addition, Christie played the role of a facilitator rather than that of a supervisor of a given practical task. She was in charge of the distribution of equipment and chemicals to students and saw to it that activities ran smoothly. I saw her now and then joining groups in order to elaborate on some problems, ask thought-provoking questions or provide some hints when the students were stuck about the next step to take. Most of the time she encouraged students to read their manuals before they asked her for any assistance.

In sum, Christie considered reading and being prepared for lab activities to be essential in carrying out practical activities. In her view, when students come to class unprepared, they usually have the tendency to disturb the smooth running of practical activities and a lot of time is usually wasted. Most students tend to skim read while doing practical activities. Skim reading is not bad in itself but one needs to have the whole picture in mind before taking any step or deciding on what should be done. Students can easily end up with wrong results simply because of not reading what they have to do with understanding before commencing on their work. Similarly, Bennett (2003) posits that reading rarely takes place in science lessons. According to her, many modern school science textbooks have short paragraphs that seem not to support extended periods for reading.

4.2.1.2 Jarijo

In this subsection I have analysed and discussed the data dealing with Jarijo's conception of practical work (i.e. the kind of practical work she involved her students in as well as the manner in which she prepared the students for practical work). I believe that this type of information will provide relevant information about Jarijo's laboratory teaching styles and classroom practices.

a) The Jarijo's conception of practical work

Although Jarijo is a young unqualified biology teacher with only three years of teaching experience, her teaching style resembled very much that of Christie. This is perhaps as a result Christie's mentoring. The latter as the Head of Department in School A was responsible for grooming the former on how to run a school biology lab. There were many similarities between Christie's and Jarijo's teaching styles. Similarly, Jarijo presented lectures on the theory under discussion and hold pre-practical discussions while she was teaching theory and then, she would finally ask her students to undertake biology practical activities in small groups. However, unlike Christie, Jarijo did not arrange discussions classes after the practical activities. Also, like Christie Jarijo did not involve her students in teacher demonstrations in all the sessions I observed.

Jarijo's biology classroom had a normal flat floor unlike Christie's classroom which was built in the form of an amphitheatre. In addition, Jarijo used a separate biology laboratory with long benches and typical tall laboratory stools for the students. The teacher's working station was fixed in the front part of the laboratory. There were also long built-in benches alongside the walls of the laboratory and five long benches fixed in the middle of the biology laboratory. However, there were fewer science projects on display compared to Christie's biology lab. Most of the apparatuses and materials were kept in Christie's biology laboratory and when other teachers needed to make use of these equipment they borrowed them and upon finishing returned them to Christie's laboratory. The excerpt below indicates Jarijo's perception of practical work:

> Practical work is the ability of the child to take what they know and put it into practice. In another words they have to apply what they have learn. So if I have taught them about a specific statement or definition or whatever, they should be able to apply it and see … does it really mean what was said in the notes or what?

Jarijo was more concerned with the application of knowledge to familiar or novel situations. What matters most to her was to enable the students to be able to put knowledge gained into practice. The word ‘practice’ here refers to ‘what students will do during practical work.’ Jarijo focused more on illustrating the scientific concepts on what was intended to be learnt. This was evident from direct classroom observations. Her students were mainly involved in illustrative practical activities such as observing colour changes when, for example, starch or simple sugars are present in food samples as well as to illustrate that there is starch present in a living leaf because of the production of food in green leaves through the process of photosynthesis.

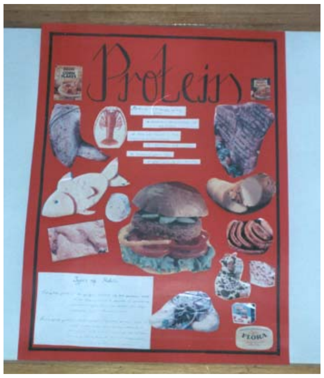
b) Types of practical activities

Although Jarijo had taught in School A for only three years, she later on told me that she had no teaching qualification. Having little experience in pedagogical content knowledge (e.g. see Hewson, 1996), Jarijo relied largely on her subject content knowledge and the experiences she picked up while at the university during practical work. She also revealed to me that during her first year of teaching, the subject head who was an experienced biology teacher provided assistance to her by giving her hints on how to go about the teaching of biology. Other senior biology teachers also readily assisted her whenever she needed their help, especially in the organization and teaching of the practical work. She also indicated that she picked up most of her experience of pedagogical content knowledge through the assistance that she received from Christie. When Jarijo was asked to describe the types of practical activity she involved her students in, she responded as follows:

> It depends on what type of activity it is. With the grade 11 I tend to let them do it [practical work] themselves. For example, I will explain at the beginning and then they have to do it themselves because when the exam time comes I won’t be there to explain to them and to do it for them. They should be able to read it and do it themselves. That’s the main focus especially when I am dealing with higher level students.

Jarijo had a strong conviction that the starting point for practical work was to provide assistance at the beginning and then to let the students carry out the practical activities for themselves and with little assistance from her side. I noticed that it was not even necessary for her to provide explanations because the laboratory manuals for biology practical work were written in a clear and concise manner. Mortimer and Scott (2003) have maintained that teaching sequences tend to focus on developing technical skills rather than pay explicit attention to the nature of discourse surrounding the activities in order to develop a scientific story. Furthermore, they posit that there is a need to link planning to the teaching activities and purposes. For example, further supportive dialogue is needed to guide students in order to work on scientific ideas, give thoughts not only to what they will be doing but also to motivate them to talk through scientific views amongst themselves (Chin, 2006; Mortimer & Scott, 2003). Although Jarijo seemed to have very clear and transparent thoughts about what practical work in biology entailed, there was little effort made from her side to involve the students in dialogue in order to clarify what they have observed.

When I walked into her class, I noticed some posters hanging at the back of the class. She indicated that these were from the projects conducted last year by the grade 11 students. Jarijo also used a similar style of giving different activities to students in different grades every year as Christie. This was also strong evidence that the whole school as from grade 8 through to grade 12, students were involved in various type of practical work. Examples of some posters are presented overleaf but these posters were not produced by the group of students whom I was observing at the time of data gathering.



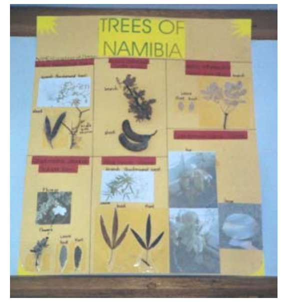


Figure 4.2 Posters on types of food sources and a sample of an indigenous tree

As explained in the earlier chapters, the students in School A including those in Jarijo's practical sessions were disciplined and followed the general routine which I observed in Christie's classes. Mostly and importantly students worked in small groups like in Christie's practical lesions. As from my observations, although the students grouped themselves in small groups inside racial lines, language played also major role. The students who spoke Afrikaans fluently worked together in a small group and in addition, girls also preferred to work together than working in mixed groups of boys and girls. Similarly, Jarijo, too, did not like the idea of arranging teacher demonstrations. She indicated that in normal situations she did not do demonstrations unless those needs arose. Responding to my reflective question on whether she provided opportunities for teacher demonstrations, Jarijo said:

> I normally I don't do it [*demonstrations*] but in the lower grades where they are not used to be in the lab alone. That is why with grade eight and nine we take them to the lab already and that is the time when I have to do it myself, I explain it to them whatever and then by the time they get to grade 11 and 12 they already know the equipment and they know what is expected of them. So they can go on all by themselves.

I found the students in Jarijo's practical sessions working in small groups like the students in Christie's session. Jarijo indicated that she preferred students to work in groups but not too large groups. She argued that when they work in groups, students interact with one another to make important decisions about what they should do. She also added that it could be intimidating to some students when they work individually on practical tasks because there is no one to talk to. For example, she said:

> To stand there and you don't know what to do and you don't have friends around you, you know, it could be frustrating the way one is experiencing it there at the university, it is hell when you are standing and you have all the things and you have no idea where to start. Well, to me it is good [working in groups]. I want them to interact with each other and get what the other person is thinking about and apply it.

When I asked Jarijo whether she involved her students in investigations, she said: "at the moment I am not involved in teaching biology to grade 10. Investigations are conducted when students are in grade 10 and they are done in Life Science."

In sum, although Jarijo provides opportunities for students to 'allow the students to see the concept in action and so relate to theory more closely to reality' (Gott & Duggan, 1995, p. 21) there still a need to do more investigations, practical tasks that will centre on graphing skills and conceptual skills rather than purely the acquisition of procedural skills on practical work. The next section deals with how Jarijo prepares her students for practical work examination.

c) Preparation of students for practical work

In order to stress the point that practical work is made a priority at School A, Jarijo narrated a similar story as Christie. The excerpt below illustrates the status that practical work enjoyed in school A:

> Grade eights and nines first we teach them all the equipment. I take all the equipment out and put them out for them and show them that this is a Bunsen burner. You do this and this with it so they have an idea and they know exactly this is what you do with it. I explain safety precautions and things because you

> are in the lab. Precisely we do these things in grade eight and nine and I do simple experiments like again testing a leaf for starch. You can do that with them as well as showing them how to use a Bunsen burner, how to treat a leaf and all of those things. So by doing simple experiments I prepare them for grade eleven and twelve work. With the new syllabus it is compulsory for the grade nines. I did it last year with the grade eights and nines and I am doing it this year again. If I talk about a Petri dish they should know what it is and what to use it for.

What I found to be fascinating was that when grade 11 students entered the laboratory they simply sprang to work. They did not wait for Jarijo to tell them what to do. They already knew where the chemicals where placed, how to control Bunsen burners as well as the general safety precautions were adhered to. The noise was minimized and all the students were working in their small groups on similar tasks per session. This seems to be a good example of gradually and systematically inducing students into the world of scientific practices as well as reducing the physical and the mental noise of practical work. Under such conditions, students may then have a chance to perceive the 'learning signal' (Hodson, 1993, p. 100) and may have fewer responsibilities unlike what Hodson (1993) remarked that practical work overload students with responsibilities and information.

In conclusion, because of the policy that existed at School A, the students were provided with a lot of opportunities to be able to learn and practise the basic procedural and conceptual skills over a period of four to five years. Such a system tends to benefit most students in practising practical skills as well as initiating them into the social culture of scientific practice as compared to short lived practical activities (Cossa, 2006; Gangoli & Gurumurthy, 1995; Haambokoma, 2007; Nakhleh et al., 2002).

4.2.1.3 Lena

At the time of data gathering Lena had eight years of pedagogical knowledge in teaching biology at School B. Lena was the only Biology teacher at school B. She taught the normal classes as well as the practical work session in the Biology laboratory that was adjacent to the Physical Science laboratory. The Biology laboratory benches were not fixed in the normal way that a modern laboratory was arranged. There were cupboards fixed all around the walls and seven laboratory basins fixed on top of the cupboards. There were also taps for both gas and water available but these taps were non-functional. The walls of the Biology laboratory were bare, with no relevant posters or models as compared to Christie and Jarijo's classes. However, there were some posters in the Biology laboratory but these were not relevant to the topic at hand.

Lena's station was fixed in the front part of the laboratory and behind it on the wall was a chalkboard. The teacher's working station was build a little bit at higher level than the normal floor where the benches and normal chairs for the students were. As said in Chapter 3, the laboratory was overcrowded and there was little space for the students as well as for the teacher to move freely. There were up to 39 students in the laboratory. Some of the students enrolled for higher level and other for ordinary level examinations.

Unlike the students at School A, students at school B were highly undisciplined. After entering the laboratory, the students took time to settle down and Lena struggled to discipline them. The students seemed not to be serious with the practical tasks at hand but most of their discussions were off-tasks discussions most of the time. Now and then I could hear Lena silencing them: "Keep quite. You there go sit down. We want to start with the practical work." One day the students took up to three minutes to settle down and the normal practical session could continue.

After observing her lessons for few days I also arranged a formal interview session with Lena in order to obtain additional information about her conceptions of practical work. I used the following questions in order to get additional background information about her conceptions of practical work:

1. What comes to your mind when you hear the word "practical work"?
2. What types of practical work do you like to involve your students in most of the time? Explain
3. Explain how you prepare your students for practical work.

a) Lena's conception of practical work

Lena used teacher demonstrations as a way of providing practical opportunities to the biology students. At times the students assisted the teacher to carry out demonstrations. Although Lena lectured like Christie and Jarijo, she did not encourage class discussions both during and after practical sessions and also did not use any laboratory manuals. Lena indicated that it was difficult to describe the concept of practical work as it involves different things. She described practical work as an activity that involves different things, for example:

> One, is where the child just observes say an experiment or something that happened in the class. Two, it can be actually an experiment. Three, it can involved them [students] in biological drawings, doing labelling, something, doing a drawing. Four, or interpreting a graph or any kind of data that is in front of the student. That is to me practical work. So, is basically observation and experimenting and working on the data that a student gets. That is basically what I think is practical work.

Lena's conception of what practical work entails opens up more opportunities to allow students to carry out varieties of practical activities. This is in line with Millar et al. (1999) definition of practical work as being all those teaching and learning activities which involve students in handling and observing objects or materials in science instructions. The role of Lena is vital and allows her to filter through the Biology syllabus in order to arrange practical activities that should provide different practical experiences to students (Ntombela, 1999, p. 124). Lena provided some interesting revelations about her own teaching style in the excerpt above. She has a broad conception about what practical work entails and such a notion will be very beneficial to her because she will not hesitate to arrange practical activities for her students. She further said:

> Actually there are various modes of applying the results that the child obtained. So is not necessary that you have to do an experiment, it could either be a worksheet or something or just answering questions. The student must be able to apply what she/he has been taught.

Lena was aware of the need to use her students' results in various ways. Such notions might indicate that examples of practical activities could be conducted within the normal classroom rather than being in the laboratory only. However, from classroom observation I did not notice any practical activities that were arranged in the manner that Lena indicated. Worksheets were only used during practical activities in the laboratory. Worksheets contained important information about the procedures of a practical activity, warning and few questions that all students needed to complete after completing the observations in the biology laboratory in order to allow for conceptual manipulation.

b) Types of practical activities

Lena indicated that she regularly demonstrated different types of practical activities for her students. By adopting from time to time various approaches to practical work she was able to impart critical process skills to her students. According to her, one should not impart too many skills in one session because it would be difficult for the students to cope with them all. Likewise, Hodson (1996b) argues that practical work is loaded with too many responsibilities and information. Moreover, to develop too many practical skills in a practical lesson might overload students and hence, practical work might be ineffective. Lena further pointed out that she tried to develop only a practical skill in a given activity. Her reasoning was that it would be unhelpful to overload students with tasks demanding different learning outcomes as these might eventually confuse them. Her focus therefore, revolved around practical activities that helped students to develop essential process skills such as interpretation of graphs, planning or designing an experimental activity, observation and writing conclusions.

At the time of data collection, Lena demonstrated a rather broad view of practical work. Thus:

> What I have tried this year is to change it [the way she teaches] where I simply give them a graph, then they have to interpret a graph. Then I give them something else so that they can have skills of planning and applying and interpreting too. Then sometime I give them [students] data that they must solve so that in the end the five skills on practical work have been done.

Lena further indicated that she conducted teacher demonstrations on food tests in order to allow students of observe what was happening. Although she did not compile a laboratory manual for her students, she used worksheets regularly. Her worksheets had a general format with instructions for the procedures, some hints on safety precautions and a space where the students could write results and conclusions. In addition, there were also questions (taken from past examinations) that the students expected to answer.

Lena explained that it was essential for her to let the teaching progress slowly in order to avoid confusion. For example, she said: "I let them first observe and then afterwards let them interpret the results." Rather than "letting them do the practical and just write a conclusion," Lena added that:

> We also do some excursions, as practicals. I take them out to for specific reasons, for example, the breweries for fermentation, to the sewerages, that large part of the sewage, to observe the effect of sewage on the environment. So, I take them to all sorts of places. I sometimes take them out to the factories say the chocolate factory, so that they can see how it is done in the business itself.

From the above excerpt it can be deduced that Lena's idea of what practical activities entail was much broader than what many of her counterparts in Namibia would regard as practical work. Therefore, to put her message about practical work across to her students she included a variety of practical tasks. As an experienced teacher, she defined practical work in terms of its many activities. For example, she included various tasks such as observation activities, making of drawings, labelling drawings, interpreting graphs, and working with given data (Bekalo & Welford, 2000; 1999; Brown, 1995; Henry, 1975; Millar et al., 1999). In addition, she also agreed with Jarijo about the application of what was taught to both familiar and new situations.

After several observations I realized that Lena was not in favour of discussion lessons particularly after practical sessions. She neither provided time for discussion to iron out misunderstandings nor feedback on how students had performed in a given laboratory session. Responding to my question on why there was no provision made for the discussion of experimental results, she made the following defence:

> Well, it could be done because I, first look at the results and then I come back and if and every one of these results are wrong. I ask them why they get those results. And based on that I will tell them what was the mistakes that were done with the practical and how they can improve on it. If it is necessary, do another one again. Do another practical, so that at least they now suppose to improve on the results.

The excerpt provides some interesting information. It reveals Lena's weaknesses in organising appropriate discussion forums during or after practical activities. Although the need was there, Lena seemed to ignore the students' immediate needs by not providing feedback in time when students could discuss their misunderstandings. I went further and looked at the students' workbooks. There were some differences between what I observed from practical sessions and the comments in the workbooks. Lena argued that she was not yet done with the books although the workbooks were ready to be given back to the students. She reasoned that she needed to add more information to the workbooks. She revealed that she did not like writing remarks in students' workbooks because sometimes students do not take remarks in a positive way. Students get easily embarrassed when they got a lot of remarks from the teacher. Lena indicated that she:

> Rather will write 'good' or 'excellent' but will not tell students who did something bad. I will rather write notes about what are the problems of each on say a graph and then in the end when I go back to class when we do different practicals, I then tell them that 'this was the general problem'. So that even though the other students did well and they might make the same mistakes. So I tell them this is what went wrong and this is what you must look out for so that it must not happen again.

What I observed seemed to be different from what Lena stated in the excerpt above. Lena did not provide a single feedback on the practical work (or better still, demonstrations) during the period of data collection. While avoiding the danger of telling students everything thus killing their inquisitiveness, teacher demonstrations without specific feedback and discussions on what is to be observed or what has been observed by students cannot be regarded as a good instructional practice. It is apposite to point out that the progression from the observations of phenomena to the construction of scientific ideas is difficult. Scientific ideas are counter intuitive and need to be constructed through talks or discursive reasoning under the supervision of the teacher (Chin, 2006; Flick, 2000; Jones, 2000; Liang & Gabel, 2005; Qhobela, 2003; Roth, 1995; Tobin & Tippins, 1993). As a part of the role of the teacher, Lena needed to focus on key aspects of a demonstration in order to point out crucial factors that could lead to confusion. Demonstrations or a passive activity (a sit and watch demonstration) alone is insufficient in that little opportunity exists for cognitive skill development (Hudson, 1994; Watson, 2000). In other words, talks and feedback are essential in order to accelerate students' conceptual understanding.

When I asked Lena whether she involved the students in investigations, she made the following response:

> No. Sometimes we do, especially when it comes to some topics in the syllabus that include human influences on the environment. That's when I let them do their own investigations.

Human influences on the environment are taught when students are in grade 12. It is the last topic within the Biology syllabus for grade 12. Unfortunately, the grade that I observed was grade 11 that was not yet involved in any investigation at the time of data collection. Upon questioning her whether or not she gave projects to students, Lena indicated that she did so a few years ago and no specific time was given. What is important to me is that the group that I observed did not do any projects at all.

c) Preparation of students for practical work

Like her counterparts, Christie and Jarijo, Lena also indicated that she prepared her students for practical work. However, there was a difference in how Christie and Jarijo prepared their students at School A as compared to how Lena prepared her the students at School B. Lena pointed out that she only introduced her students to practical work for a few weeks at the beginning of grade 11 compared to Christie and Jarijo who started initiating their students to practical work as from grade eight. Lena indicated that:

> I show them different types of practical work and give them short demonstrations on how to do the writing up of it, how to answer the questions so that they can come up to a conclusion. Most practicals in the syllabus are based on how to analyse results, how to use data and interpret it. I do that at the beginning of the year so that they at least know what is expected of them.

This does not seem to be realistic because the period is too short for the students to acquire the needed basic skills that will enable them to write the 'Practical Test" or in the 'Alternative to Practical' examinations. Preparation of students for practical work is certainly very important and it is equally essential to spend more time in preparing students in order to allow them to acquire basic practical skills as well as procedural and conceptual skills that will enable them to carry out practical activities appropriately.

As stated before practical work entails both conceptual and procedural skills. It involves both mental and physical activities that are based on theory. However, practical activities are not conducted in a vacuum (Bennett & Kennedy, 2001; Hodson, 1996b). As a result, the three biology teachers, Christie, Jarijo and Lena have different conceptions of practical work. For example, Jarijo considers practical work to involve students in activities in order to exercise what was taught in the theory lessons. Based on the classroom observation, Jarijo used practical lessons to confirm what she taught in theoretical lessons. On the other hand, Christie's and Lena's conception of practical work included a variety of practical activities which could be used to develop students' practical skills and scientific understanding. Christie and Lena's conceptions of practical work agree with other scholars' (Bekalo & Welford, 1999; Brown, 1995; Millar et al., 1999) notion of practical work in terms of what the students do both physically and cognitively (Tamir, 1991; Watson, 2000; Wellington, 2000; Woolnough, 2000).

Another common feature from all the three teachers was that they provided opportunities for their students to develop different procedural and conceptual skills. Both Christie and Jarijo at School A used small group laboratory instructions while Lena, at School B mainly used teacher demonstrations and to a lesser extent investigations and field trips. In addition, Christie and Jarijo at School A offered opportunities to students for practical work right from grade 8 to 12. As a result they had ample time to prepare students efficiently in most of the basic procedural and conceptual skills while the students at School B had time to acquire the intended practical skills within 15 to 16 months. In other words, the students at School A had a chance to experience and practise most of indented procedural and conceptual skills as described in the biology syllabus over a period of five years before writing the practical examination.

Practical work is not as rosy as it seems to be in that it entails a congeries of aims, purposes and activities. Practical work is defined in different ways in relation to either its aims, activities or the focus. But despite the variety of what it entails, there is a consensus among scholars that it involves students' hands-on experiences. It is a dynamic endeavour which entails a teacher, students, materials and interactions (Bekalo & Welford, 2000; Brown, 1995; Donnelly, 1998; Henry, 1995; Hodson, 1996a; Millar et al., 1999). From the interviews with the teachers, it seemed that the teachers were well aware what practical work entails. For instance, they identified a number of activities which are likely to enhance students' conceptual understanding and the development of procedural skills. As a number of scholars have indicated, a teacher's belief or conception of practical work can impact directly in the way s/he arranges practical work. As mentors, facilitators and teachers should have a clear understanding of what practical work entails and the purposes it serves. Having a clear understanding about the nature of practical work will help the teachers to plan teachable practical activities (Clackson & Wright, 1992; Gott & Duggan, 1995; Leach, 1999).

If teachers misunderstand the nature of practical work they are likely to be restricted in their thinking. The way they arrange a variety of practical activities is critical to the development of students' procedural and conceptual skills. Practical activities provide opportunities for students to be imaginative, creative and daring. Practical work exposes students to vital experiences of success and failure, difficulty and easy tasks, collaboration and disappointment (Jenkins, 1999). Practical work as a pedagogical strategy should equip students with new knowledge that was not hitherto available. In other words, practical work will only be meaningful if it is linked to familiar subject content or appropriate aims rather than taught in a vacuum (Bennett & Kennedy, 2001; Hodson, 1996b; Hodson & Bencze, 1998). The NSSC H- and/or O-level biology syllabus seems to identify most of the practical skills in detail appropriately. But what needs to be examined is how learning outcomes are taught and the results are shown in the later sections.

There is a difference between the instructional practices of Christie and Jarijo on School A, on the one hand and Lena in School B on the other hand is worthy of closer analysis. Question 1 of the study, is concerned with determining to what extent the three biology teachers used practical work to develop investigative and procedural skills among their students. The observations revealed that most of the practical activities conducted in both schools were illustrative practical work (Frost, 2005; Ogborn et al., 1996) at different levels of complexity. Lena focused on illustrative demonstrations that included less practical activities to develop higher level practical skills while Christie and Jarijo focus on practical activities that allowed students to exercise higher level practical skills. In other words, Lena seems to deviate from what was recommended in the Biology syllabus. There is consensus in the literature about the merits and demerits teacher demonstrations. Some of the merits of this instructional approach include:

- Allowing students to confront natural events directly in a contrived laboratory situation;
- It is stimulating and rewarding for students;
- The students gain first-hand experience of scientific phenomena;
- Students experience manipulation of equipment;
- Provides students the opportunity to observe classical experiments that are too difficult or dangerous for their level of development;
- Facilitates students' spectator or practical experience;
- Offers opportunities to acquire and comprehend complex and abstract subject matter
- Offer opportunities to students to participate in real investigations;
- It gives students an opportunity to appreciate the spirit of science;
- It promotes problem-solving skills;
- It allows students to act like a real scientist;
- Develop important attitudes such as honesty, readiness to admit failure and critical assessment of results and of limitations (scientific attitudes);
- Offers opportunities to students to identify their misconceptions;
- It has enormous potential for exciting students;

- Serving as a means to assess students' performance especially in a situation where there is a lack of materials (e.g. Driver et al., 1994; Ebenezer & Connor, 1998; Frost, 2005; Ogunniyi, 1986; Olson, 1991; Osborne, 1997; Solomon, 1994a &b; Tamir, 1991).

On the other hand, the demerits of teacher demonstrations might be experienced, particularly, when there lack of teacher assistance. Meaning during a teacher demonstration can only be disentangled from materials action through a teacher talk, actions, and dialogue with students. Such merits include:

- Visibility problems - not all students get the same results;
- Limited opportunities for students to become familiar with learning materials;
- Lack of physical resources;
- Lack of dialogue of what is happening at the same time as doing the practical activity;
- It is not the best way to help students to achieve the learning outcomes;
- Do not explain things to students;
- Not all results support the learning outcomes;
- Sometimes things do not turn out as expected and students can be left confused;
- There is a need to explain unexpected results;
- If things go wrong or fail, it can actually confuse rather than illuminate laws and theories;
- Hidden reluctant behaviour of teachers not to teach topics where they cannot carry out practical work. Many controversial topics could be neglected due to such views;
- The use of 'cookbook' in the laboratory may force students to mindlessly follow procedures;
- No opportunity to identify problems or to formulate hypotheses;
- There are relatively few opportunities to design observation and use measurement procedures;

- There are even fewer opportunities for students to design experiments and to work according to their own pace;
- Students are not encouraged sufficiently to discuss limitations and assumptions underlying their experiments
- Students are not encouraged to share their efforts even in the laboratory activities where that is appropriate;
- There are no provision for post-laboratory discussion, consolidation of findings and analysis of their meaning;
- Not all scientific information can be grasped by sight and sound alone (e.g. odours and texture require close observation and touch respectively (Frost, 2005; Gunstone, 1991; Ogborn et al., 1996; Ogunniyi, 1986; Olson, 1991; Tamir, 1991; White, 1991).

Lena involved her students mainly in simple practical skills such as following instruction, making observations and recording data rather than high-order practical skills. This finding is consistent with previous research findings indicating a mismatch between the intended goal and the learning outcomes. In addition, teacher demonstrations that are not appropriately planned tend to deny students essential opportunities to develop complex procedural and conceptual skills, especially when dialogues between the teacher and the students are not encouraged (Bekalo & Welford, 2000; Chacko, 1997; Hattingh et al., 2007; Ramorogo, 1998). I would say that if teacher training on practical work is improved, this in turn, is likely to improve the teaching and learning of practical work. In the words of Pickering (as cited by Tamir, 1991, p. 20):

> What is needed is more careful planning and precise thinking about educational objectives. By offering a genuine unvarnished scientific experiences, a lab course can make a student a better observer, a more careful and precise thinker and a more deliberative problem solver.

I will now move on to consider the NSSC H-and O-level biology syllabus and worksheets on the intended learning outcomes and then describe how these learning outcomes were implemented by the selected teachers as well as how they were experienced by their students during practical sessions.

4.2.2 Documentary data

In this subsection, I have analysed and discussed a part of the relevant documents NSSC H- and O-level biology syllabus (2006) that biology teachers used to provide opportunities for the intended learning outcomes for practical work in Biology Education in Namibia. I have also analysed documents on students' practical workbooks to determine to what extent Christie, Jarijo and Lena used practical work to develop procedural and investigative skills among their students. These documents provided the intended learning outcomes for practical work in grades 11 and 12. The NSSC H- and O-level biology syllabus content is covered over two years, that is, grade 11 students set off with the Biology syllabus and then complete the syllabus in grade 12 after which they take final externally marked examination in practical work.

4.2.2.1 The NSSC H- and O-Level Biology syllabus and the teaching of practical work

Although the Ministry of Education prescribed that Biology teachers should undergo training in teaching practical work, only Christie and Lena had had any training by the time the study was conducted. They had both attended a one-week workshop each on how to teach practical work as a part of their in-service training. According to both teachers, the teaching was mostly theoretical and less on hands-on activities. In addition, they wrote a number of assignments before they were deemed qualified to teach practical work in schools.

The Ministry of Education expects all Biology teachers to teach by the prescribed syllabi with directions and guidelines for teaching of practical work in Namibian schools. For this reason, I considered an analysis and interpretation of the Biology syllabus as crucial because it provides essential information about the teaching and assessment of practical in Biology in Namibian schools. The NSSC H- and O-level biology syllabus describes the assessment objectives for practical work and these learning outcomes are described in Table 4.1 and Table 4.2.

Table 4.1: NSSC H-Level Biology syllabus (2006)

Domain C: Practical (Experimental and investigative) Skills and Abilities	
Skill 1	• Follow sequence of instructions; • Use appropriate techniques; • Handle apparatus and materials competently; • Have regard for safety.
Skill 2	• Make and record estimates; • Make and record observations; • Make and record measurements accurately
Skill 3	• Handle and process experimental observations • Handle and process experimental data • Deal with anomalous or inconsistent results
Skill 4	• Apply scientific knowledge and understanding to make interpretation from practical observations and data • Apply scientific knowledge and understanding to draw appropriate conclusions from practical observations and data
Skill 5	• Plan, design and carry out investigations • Suggest modifications in the light of experiences

Table 4.2: NSSC O-Level Biology syllabus (2006)

Domain C: Practical (Experimental and investigative) Skills and Abilities	
Skill 1	• Follow sequence of instructions; • Use appropriate techniques; • Handle apparatus and materials competently; • Have regard for safety.
Skill 2	• Make and record estimates; • Make and record observations; • Make and record measurements accurately
Skill 3	• Handle and process experimental observations • Handle and process experimental data • Deal with anomalous or inconsistent results
Skill 4	• Apply scientific knowledge and understanding to make interpretation from practical observations and data • Apply scientific knowledge and understanding to draw appropriate conclusions from practical observations and data
Skill 5	• Plan, design and carry out investigations • Suggest modifications in the light of experiences

The practical skills and abilities in Tables 4.1 and 4.2 above are arranged in order of difficulties starting from skills 1 (less difficult) to skills 5 (most difficult). For instance, in order to be able to plan, design and carry out an investigation, a student needs to have acquired skills at the lower levels, such as skill 1, skill 2, skill 3 and skill 4. Take note that these practical skills at the Higher level are similar to those taught at the Ordinary level in both syllabi. The only difference lies in that students who enrol for the Ordinary level take the 'Applied Practical Skills" examination while those who enrol for Higher level examination take the 'Practical Examination' examination at the end of grade 12. The 'Applied Practical Skills' is a theoretical paper that assesses students' practical skills as prescribed in the NSSC O-Level Biology syllabus. This paper is designed to test the students' familiarity with laboratory practical procedures. Questions may be set requiring the students to develop the ability to:

- Carry out a sequence of instructions;
- Use familiar and unfamiliar techniques, record observations and make deductions from them;
- Recall simple physiological experiments, e.g. tests for food substances and use of hydrogen-carbonate indicator and litmus and Universal Indicator paper;
- Recognize, observe and record familiar and unfamiliar biological specimens;
- Make a clear line drawing from a photograph (or other visual representation) of a specimen, indicate the magnification of the drawing and label, as required;
- Perform simple arithmetical calculations;
- Apply knowledge and understanding to make appropriate conclusions from practical data provided (MEC, NSSC O-Level Biology Syllabus, 2006, p. 34).

While the 'Practical Examination' assesses students' practical skills and abilities as prescribed in the Higher level syllabus. The practical examination is a hands-on examination. For example, students may be asked to carry out exercises involving:

- The ability to carry out a sequence of instructions;
- The use of familiar, and unfamiliar, techniques to record observations and make deductions from them;
- Simple physiological experiments, e.g. tests for food substances and use of hydrogen-carbonate indicator and litmus and Universal Indicator paper;
- Manipulative skills using scalpel or razor blade, forceps, scissors and mounted needles;
- The making of a temporary slide and subsequent examination under a microscope;
- The interpretation of an electron micrograph;
- The use of a hand lens of not less than x 6 magnification for the recognition, observation and recording of familiar and unfamiliar biological specimens;
- Clear line drawings of specimens provided, an indication of magnification of the drawing and labelling as required;

- The use of an identification key or requirement to devise a key;
- Simple arithmetical calculations. (MEC, NSSC H-Level biology syllabus, 2006, p. 40).

The NSSC H- and O-level also contain suggestions for practical activities which students are expected to be familiar. At the time of data collection, the teachers focused on teaching nutrition and plant nutrition and the suggested practical activities read as follows as per topic respectively:

Nutrition

1. *Describe an carry out food tests on a variety of food substances:
    a. Benedict's test for reducing and non-reducing sugars (qualitative only);
    b. Iodine test for starch;
    c. Biuret test for proteins;
    d. Ethanol test for fats and the ;
    e. DCPIP test for ascorbic acid (vitamin C) and the be able to evaluate results;
2. *Design an experiment to investigate the relative concentrations of vitamin C in different fruits or fruit juices;
3. *Investigate the distribution of carbohydrates, fats and proteins in different parts of a seed or fruit (p. 9);
4. *Carry out starch test on leaves;
5. Investigate the effects of the absence of light, chlorophyll and carbon dioxide on starch production;
6. Design and/or carry out experiments to investigate the effect of varying light intensity and/or wavelength on the rate of oxygen production by water and weed;
7. Separate the different pigments in leaves using paper chromatography;
8. Investigate the effects of lack of nitrogen, magnesium and iron on the growth of green plants;
9. Observe, draw and interpret prepared slides of transverse sections through a leaf;
10. Make temporary mounts of the upper and lower epidermis or epidermal impressions of a leaf (using nail varnish) (p. 10).

Practical activities that were conducted at the time of data collection centred on those activities which are indicated with an asterisk (*).

None of the three biology teachers observed covered all the suggested practical activities. Also while the teachers at the two school sites involved their students in similar practical activities the approaches they used differed. All the three teachers complained about insufficient time to carry out all the suggested practical activities. According to Christie, "It is hard. The lab is small and there are many kids. So, it takes a lot of time to get them through all the practical activities and keeping them under control is also difficult." Similarly Lena claimed that, "Time is against us. The amount of time per period is also against us, especially, when it comes to practicals like photosynthesis." All the three teachers complained that their students were many and the classes were overcrowded. Their biggest problem was that they did not have enough materials and chemicals to allow the students to carry out all the suggested practical activities as described in the NSSC H- and O-level biology syllabus.

The practical skills presented in the NSSC H- and O-level biology syllabus paint a far rosier picture of the type and extent of practical work undertaken in schools than what I observed at the time of data gathering. The skills described in the biology syllabus are open to multiple levels of interpretations. Hence, a teacher might believe that s/he is engaging students in various practical skills while another person might view it as being only a few practical skills due to implicit descriptive nature of practical skills depicted in the syllabus (Donnelly, 1998; Roberts & Gott, 2000; Sadeck et al., 2003; White, 2003).

A second point to consider is that of training teachers for a few weeks. The situation where teachers receive training for a week or two is not enough. More time is needed to train teachers appropriately to teach practical work to implement all the intended learning outcomes as described in the syllabus. The implication is that if teachers possess limited practical skills they, in turn, will impart only limited skills to their students (Sadeck et al., 2003; Tamir, 1991). Thus, the intentions of the NSSC H- and O-level syllabus will not determine whether the practical work or what type of activities is conducted but the decision of the teachers will have a far greater impact on the implementation thereof (Hattigh et al., 2007; Maboyi & Dekkers, 2003; Tamir, 1991; White, 2003). My view is that the teachers need to acquire a special approach to teaching practical work and special instructional skills.

The next section deals with practical activities and skills as intended in the NSSC H- and O-Level Biology syllabi.

4.2.2.2 Practical activities and practical skills

Further analysis of the biology syllabus revealed at least two interesting implications for the study. The first deals with the extent to which they (teachers) used practical activities to develop the prescribed practical (experimental and investigative) skills among the students while the second is concerned with how the students were exposed to developing different practical skills as prescribed in the NSSC H- and O-level biology syllabus. In this section I have analysed and interpreted the students' worksheets and practical activities for the intended and implemented practical skills as follows:

a) Activities carried out in small group

The students carried out six practical activities in small groups at School A. As alluded earlier, the practical activities were clearly described in the laboratory manuals and centred on nutrition and plant nutrition. The students in small groups spent time on carrying out six practical activities, practical activity 19, 20, 21, 22, 23 and 24 which dealt with test for starch, test for a sugar such as glucose, test for sucrose, test for proteins test for fats and a general test for food samples of their own such as apples or any other fruit respectively. All six practical activities were arranged in a similar way, that is, the aim, the procedure, results and questions of varying degrees of difficulty (See Appendices E -J).

Table 4.3 **Intended and implemented practical and investigative skills performed by students working in small groups**

Domain C: Intended practical skills		Implemented practical skills
Skill 1	a) Follow sequence of instructions;	a) 2/3 of time
	b) Use appropriate techniques;	b) Not observed
	c) Handle apparatus and materials competently;	c) 2/3 of time
	d) Have regard for safety.	d) ¾ of the time
Skill 2	e) Make and record estimates;	e) Not observed
	f) Make and record observations;	f) √
	g) Make and record measurements accurately	g) √
Skill 3	h) Handle and Process experimental observations	h) answer questions (mental)
	i) Handle and Process experimental data	i) not observed
	j) Deal with anomalous or inconsistent results	j) not observed
Skill 4	k) Apply scientific knowledge and understanding to make interpretation from practical observations and data	k) √
	l) Apply scientific knowledge and understanding to draw appropriate conclusions from practical observations and data	l) Not observed
Skill 5	m) Plan investigations,	m) Not observed
	n) Design investigations, and	n) Not observed
	o) carry out investigations	o) √ (all activities)
	p) Suggest modifications in the light of experiences	p) √

Table 4.3 shows the extent to which the practical activities offered opportunities to the students to develop procedural and conceptual skills at different levels of difficulties. Table 4.3 shows that all the intended practical skills were covered in all six practical activities as written in the biology laboratory manual. Each practical activity gave a potential to develop all practical skills except for the following practical skills: skill 1 (b) i.e. use appropriate techniques; skill 2 (e) namely, make and record estimates; skill 3 (i) i.e. handle and process experimental data; skill 3 (j), deal with anomalous or inconsistent results; skill 4 (k), apply scientific knowledge and understanding to draw appropriate conclusions from practical observations and data; and skill 5 (n), plan investigations; and skill 5 (o), design investigations.

For example, the kind of practical activities given to the students did not provide the opportunity for them to: acquire skill 1 (b), use appropriate techniques; skill 5 (m), plan investigations and skill 5 (o), design investigations because the activities were pre-planned by the biology teachers. Therefore, the students did not need to use different techniques to make observations or plan investigations or to design investigations for themselves. The students seemed to use the laboratory manuals blindly. Skill 2 (e) namely, making and recording estimates was excluded from all the six practical activities due to the fact that the nature of the content used did not require the skills for making estimates.

From my observations, about two third of the time was spent on skill 1 (a) and (c) and three quarters of the time on safety precautions. Skills 1 and 2 were appropriately covered while skills 2 (f), 2(g), 3 (i) and (j), 4 (k), 5 (o) and (p) were sufficiently covered in all six of the worksheets of the practical activities. Students in a group shared responsibilities. For example, one student took measurements of starch solution, while another one was adding drops of iodine solution to another solution. Another student watched the flame while another one collected more chemicals from the teacher. This is what Bentley and Watt (1992, p. 58) called "collective work'. No student carried out all the procedures but they shared responsibilities amongst themselves. In a group, students came with different range of skills and they learnt from one another's strengths. Group work allowed the students to explore, understand and act upon science ideas. It should be seen as a tool through which the students were communicating. But group work has its own advantages such as:

- It encourages communication;
- It encourages motivation and students are more confident in a group than working individually;
- Members take responsibility for each other and encourages co-operation;
- Leadership is encouraged;
- A long complex task can be shared;
- Ideas can be shared and opinions exchanged;
- Groups at different levels of knowledge and understanding can be given different tasks and work at their own pace;
- Materials can be shared if there are shortages of materials;
- Sometimes it is easy to look at a small number of students than deal with the whole class (Fairbrother, 2000; Hofstein, 1988; Wellington, 2000).

On the other hand, group work has its own demerits too. These are summarized below:

- Some students maybe passive when grouped with brighter students;
- Bright and talkative students often dominate groups and stop others participating;
- Some students maybe bored when grouped with less able students;
- Good order is sometimes difficult to maintain;
- Space is needed to have effective groups;
- It creates noise which is not appreciated by other staff; and
- When assessing, students may claim credit when they have not contributed (Fairbrother, 2000; Hofstein, 1988; Solomon, 1991; Wellington, 2000).

Group work should also be managed and not be taken for granted. For example, one student commented as follows:

> **Willy**: If your are working in this group, just that everybody wants to do it the way they want to do it. Maybe they want to do everything because there's a camera and there is Miss and whatever and everybody just wants to do the way they want to do it. Then I actually can't concentrate and all the other people in the group. So not all of us or maybe we are one or two in a group, including myself didn't get a chance to actually do something in the group. So maybe tomorrow I will do my own experiment by myself so that I can see what I am doing and understand what I am doing because today I didn't understand anything because everybody is just jumping ahead and doing the things by themselves. The one girl, she was doing everything by herself. You know, before I even knew it, the experiment was over. So I couldn't actually see what she was doing and I didn't participate a lot although I really did one, two and that kind of things make me frustrated.

In short, I wish to argue that practical activities reflected in Willy's comments above have the potential to create conflicts or disillusionment among students among contrary to what was intended in the NSSC H-and O-Level biology syllabi. Other scholars seem to maintain that students who are exposed to practical work in groups tend to outperform other students who are exposed to lectures or demonstrations. However, this view is by no means conclusive (e.g. Hofstein et al., 2005; McCarthy, 2005; Wu & Hsieh, 2006). It is equally important for students to be given a chance to plan and design investigations as well as plan investigations of their own interests in order to decide what techniques or instruments to use and practise, for instance, to identify anomalous results and making conclusions from practical observations and data (Gott & Duggan, 1995; Lin, 2007).

The next section deals with those activities that were carried out through teacher demonstrations.

b) Activities carried out through teacher demonstrations

In this subsection, I have analysed and interpreted the worksheets used in the teacher demonstrations activities. Most of the students did not carry out the activities themselves but watched Lena and few students carry out the demonstrations. Lena carried out five demonstration activities on different food sample with the help of few students. She called four students per a demonstration activity to assist her to carry out the demonstrations. Every student was responsible for a food sample (e.g. onion solution, potato solution, peanut solution and orange solution). Each student added a specific reagent to the solution and then it was shown to the rest of the student.

Lena read the procedures, the quantity of food substances that needed to be measured and also indicated to them when all students should record observations. The tables on which they recorded the observed results were constructed by Lena. The only practical skills that they could perform were: (i) recording observation results; (ii) writing conclusions for each practical activity; and (iii) answering some theoretical questions.

Table 4.4 Intended versus implemented practical and investigative skills performed by students during teacher demonstrations

Domain C: Intended practical Skills		**Implemented practical skills**
Skill 1	a) Follow sequence of instructions; b) Use appropriate techniques; c) Handle apparatus and materials competently; d) Have regard for safety.	(a) done by teacher and few students (b) done by teacher (c) done by few students (d) teacher and few students
Skill 2	e) Make and record estimates; f) Make and record observations; g) Make and record measurements accurately	(e) not observed (f) only (f) by all the students (g) done by teacher and few students
Skill 3	h) Handle and process experimental observations i) Handle and process experimental data j) Deal with anomalous or inconsistent results	(h) by all students (i) no provision made (j) no provision made
Skill 4	k) Apply scientific knowledge and understanding to make interpretation from practical observations and data l) Apply scientific knowledge and understanding to draw appropriate conclusions from practical observations and data	(k) by all students (l) by all students
Skill 5	m) Plan investigation, n) Design investigation, o) Carry out investigations p) Suggest modifications in the light of experiences	(m) done by teacher (n) done by teacher (o) done by teacher and few students (p) no provision made

It can be seen from Table 4.4 that the teacher demonstrations could only provide opportunities to students to practise Skill 2 (f); Skill 3 (h); and Skill 4 both (k) and (l) while little opportunities were provided to allow students to develop practical skills in category Skill 1 and Skill 5. It was also observed that Lena could have made provision to allow students to discuss anomalous results (skill 3 j) freely. For example, the test for fats and oils showed a positive result for the starch solution instead of a negative result. However, Lena did not alert her students about the anomalous result.

It is evident that the students at both schools were exposed to practical work in different ways. School A, where Christie and Jarijo taught, exposed the students to practical work through group work, while School B used teacher demonstrations. Christie and Jarijo arranged practical activities in such a way that the students could maximally benefit from such arrangements. Looking at the number of practical skills that the students could acquire through these seemed to be higher when compared to those practical skills that they could gain from teacher demonstrations at School B under the leadership of Lena. Teacher demonstrations seemed to benefit only those students who took part to assist the teacher in acquiring some skills only. Skills such as Skill 1, skill 2 (e), (g), Skill

3(i), (j) and Skill 5 as indicated in the NSSC H-and O-Level biology syllabus were impossible to attain since these were conducted by the teacher. But at School A the students themselves carried most of these skills by themselves and thus, could practise and acquire the intended practical skills.

Secondly, students in small groups could be involved in discussions amongst themselves when they needed to do so in School A. But in School B, Lena did not provide room for discussions during the demonstrations. The students could only observe and record the colour changes without discussions with Lena or other students. In other words, peer talks were reduced to mere copying of results without asking or confirming what they observed. I think that Lena could have opened more opportunities for the students to discussion their results with her or amongst themselves.

Thirdly, further analysis of the worksheets at School A and B also revealed some pitfalls in the conduct of practical work. Writing conclusions and using comparative language was seen to be one of the aspects of practical work that most students in Namibia find difficult (MEC, Examiner report, 2004; 2006; 2007). For example, students at School A were not asked to make conclusions from what they observed while students at School B were given opportunities to develop skills in writing conclusions.

Fourthly, none of the teachers provided opportunities for their students to acquire knowledge and skills in planning, designing and in modifying given techniques, instruments or procedures to be followed. Skill 5 demands perhaps the highest level of thinking but was omitted from all the practical tasks given to the students at the time of data collection. For example, the 'Applied Practical Skills' is designed to test the students' familiarity with laboratory procedures. In support of the above, it was also found that not many students could attain high marks on questions that required them to design experiments to test starch (MEC, Examiner's Report, 2002; 2006; 2007). This is thus, an indication that the students had not experienced experimental work. Other research (e.g. Chacko, 1997;

Ramorogo, 1998) has also shown that most of the time teachers exposed their students to low-level skills rather than high-level skills.

Moreover, demonstrations should not be seen as a substitute for real practical experience which students may need to acquire practical skills and/or understand science concepts. For example, not all students will acquire the intended practical skills if they only observe or listen to the teachers without participating in the activity. What I observed was that only a few of the students participated in the teacher demonstration at School B. My view is that these few students were given the opportunity to practise and experience some of the procedural skills such as the manipulation of materials and equipment and the measurements of solutions, as compared to the rest of the students in School B. These few students seemed to benefit more from teacher demonstrations than their counterparts who did not have such opportunities. A review of the literature reveals that demonstrations have merits and demerits. Some of the merits include:

- To illuminate/illustrate (first-hand knowledge): an event, a phenomenon, a concept, a law, a principle, a theory.
- To motivate or stimulate: entertain, arouse curiosity, enhance attitude, develop interest, fascinate.
- To challenge or confront (what if…?, Predict-Observe-Explain, why…?

The demerits of demonstrations include the following:

- Some members within a group may dominate while others play a little part.
- Some members may adopt roles where they do less demanding skills or show conceptual understanding.
- The method is not useful in developing skills such as practical techniques, procedures, tactics, investigation strategies, working with others, communicating and problem-solving (Bennett & Kennedy, 2001, p. 149; Wellington, 2000)

The next subsection deals with the students' conceptions of practical work as well as the types of practical activities they enjoyed the most.

4.2.3 Students' Interviews

In this subsection, I will focus on the analysis and interpretations of the data collected from the students' interviews. I interviewed three students before and after the practical sessions. I interviewed altogether 36 students, 18 students from School A and 18 students from School B respectively. I wanted to find out whether the students' conceptions of practical work differ from the teachers' conceptions of practical work. The following questions were asked to the students:

1. What comes to your mind when you hear the word "practical work"?
2. What types of practical work do you like the most?
3. Explain why you like these practical activities the most?

4.2.3.1 Practical work conducted in small groups

I interviewed 11 of 18 students for pre-practical and post practical sessions at School A from the 18 students at before the practical sessions started and after each practical session. I selected the students randomly and on willingness bases.

a) Students' conceptions of practical work working in small groups

I arranged the students' answers and analysed them sequentially for similar and dissimilar views. The students' responses were then sequentially summarised into four categories as indicated in Table 4.5. A closer examination of the responses of eleven students showed that the students had different conceptions of practical work.

Table 4.5 Students' Conceptions of Practical work at School A. (n = 11)

Category	Description	No of students
1	Going to the laboratory	4
2	Working in the laboratory with equipment, chemicals and materials	2
3	Doing hands-on activities	4
4	Do experiments	3

Although the analysis and interpretations of the students' responses for each category provides an overview of the ideas held by the total sample of students, it is equally useful to look at the sets of responses of individual students. This is important as it can establish consistency within the students' conception of practical work. It can be seen from Table 4.5 that 4/11 of the students consider practical work as being in the laboratory as well as involving hands-on activities, while 3/11 of the students described practical work as "doing experiments". The remaining 2/11 of the students described practical work as 'working with equipment, materials and mixing chemicals'. The following excerpt is representative of the students' conceptions of practical work:

Willy: I am getting out of the class [*laughing*] yes. I am getting out of the class and into the lab, the class next door where she (*referring to the teacher*) teaches biology.

Werner: Laboratory, labs, Bunsen burner, working with the materials like starch, testing for starch

Peter: Something that you do by yourself with your hands.

The views above reflect students' conceptions of practical work in School A. None of the students considered practical work in biology to include field work, fieldtrips or investigations outside the laboratory.

b) Practical activities mostly liked by students

The students were also asked to indicate the most liked practical tasks in biology practical work by rank ordering their choices from the least liked to the most liked practical activities on a five point scale. Table 4.6 summarizes the frequencies of students' responses.

Table 4.6 Frequencies of students' Choices of Practical Activities at School A. (N=12 students)

	Frequencies of choices of tasks liked most by students					**Total**
	Least liked 1	2	3	4	Most liked 5	
Demonstrations		/		/		2
Illustrations	/					1
Exercises	/				////	5
Laboratory work				////-	////	9
Investigations	//	/	///			6
Field trips		//	/	//	//	7
Manipulation of materials	//		//	/		5
Recording results		//	//			4
Discussions	//	///	/	/	/	8

An examination of Table 4.6 shows that laboratory work was on top of the list then followed by discussions, field trips and investigations, then followed by exercises and manipulation of materials and recording results, and lastly by demonstrations and illustrations. The students at School A showed high interest in laboratory work, discussions, field trips and investigations. The next subsections discuss some issues which emanated from the four practical activities that were mostly enjoyed by the students at both school sites.

The interview with the students provided me with the reasons why they enjoyed these practical activities the most. The students were given fictitious names in order to protect their identities. With regard to the students who liked laboratory work, some reasoned that they liked working with substances and chemicals. The following excerpt is representative of their viewpoints:

Sam: I like laboratory work because you work with chemicals, you get to see the reactions, see how things happen. I enjoy it to see things working for myself.

Ben: I like laboratory work is like I said is about experimenting with all the substances and see what will happen if you put few things together and the results which we have also learn in theory.

The excerpt above shows that Sam and Ben like many of their counterparts seemed to enjoy laboratory activities. Their views seem to resonate with what has been reported in the literature (e.g. Driver, 1994; Solomon, 1994b; Tamir, 1991) who construe laboratory work as a means to:

- Acquire knowledge from direct observation of phenomena.
- Gain experience about how substances react when put together.
- Test or confirm theories leant in class.
- Gain insight into how reactions take place.
- Clarify misconceptions or partially understood concepts.

However while Sam and Ben seemed to enjoy laboratory activities some of the students gave extraneous reasons for enjoying such activities. For instance, some students indicated that it was good to be in the laboratory in order to get away from all the lecturing of the normal theoretical classes.

Willy: I am getting out of the class [*laughing*] yes I am getting out of the class and into the lab.

R: Which class is this that you are talking about?

Willi This class next door. You see, like the teacher first give us a lesson and then we do the experiment she also tell us we go through the experiment and see what we need and how sometimes we can …not estimate but kind of predict what the results maybe of that specific experiment.

Conny expressed her negative feeling about laboratory activities as follows:

> **Conny:** I also like being in the laboratory except for all these chemicals. They make me nausea and give me a headache but that is all.

Students' interests in laboratory work may not be unrelated to their desire to satiate their curiosity and the pleasure they derive from the positive results of experiments. This is a very important point and teachers must take it up seriously. Sometimes students might seem not to be interested in what they do because they might not be comfortable with such an activity. This in turn might de-motivate them on the long run from wanting to take an active part in the laboratory.

4.2.3.2 Practical work which includes demonstrations

In this subsection I have analysed and interpreted the data gathered from the interviews with the students who were involved in teacher demonstrations at School B. Again, the students were selected randomly and on the basis of their willingness to take part in the study. The same interview questions were used as presented in the previous sections of this chapter.

a) Students' conceptions of practical work which involves demonstrations

It was observed that Lena, the biology teacher at School B, exposed her students to practical work through teacher demonstrations and classroom exercises as said earlier. The students' responses from the interviews were arranged and systematically analysed for the occurrence of similar and dissimilar views. Seven main categories about the students' conceptions of practical work emerged from the responses to the interview question. Table 4.7 shows the frequencies of the students' conceptions of practical work. These have not been ordered in any specific priority.

As can be seen in Table 4.7, slightly more than a third of the students in C3, 9/14, considered practical work to involve hands-on practical activities. For example, **Walter** described practical work as: "Physical work like what you do with your hands and that you can touch, feel and stuff not what you just do mentally."

Table 4.7 Frequencies of Students' Conceptions of Practical work at School B. (n = 14)

Category	Description	No of students
C1	Do it yourself	4
C2	Working with equipment, chemicals and materials	3
C3	Doing hands-on activities	9
C4	Do experiments	4
C5	Demonstrations	5
C6	Going out in the field	2
C7	Drawings, pictures, graphs	3

The majority of the students placed in C3, 9/14, linked practical work to what they have done physically in the laboratory. Below is Zeno's viewpoint:

Zeno: That will be work which we do, which we can look at, not by writing it down. It is more like a physical experience, doing it with your own hands in gaining experience by doing it yourself rather than learning out of a book or something like that. That is what I see as practical work.

Another student fictitiously named Zandrè as follows:

Zandrè: Things that you must do like physically that you must be part of it. You must do it with your hands to see what the results are like, like experiments and stuff, like that contain the work that you are doing to make the work clear for you as a student.

The students placed in C1, 4/14, saw the need of doing practical activities themselves but not through teacher demonstrations. Typically this is how they argued:

Laurno: Practical work is that I must use apparatus or the materials and I must do it myself. Yes.

Or that

Amy: The work that I have to do by myself on my own so that I can see maybe, I understand or not.

Equally important, a significant number of the students placed in C4, 4/14, described practical work as to doing experiments. For example, **Anna** described practical work as: “Experiments.” and another student described practical work as:

Simòne: More likes experiments like most of the time we do experiments which are very interesting to me. Just seeing how the things react with your own eyes, like when you just write about things, you don’t actually see how that things take place with your own eyes. For me, seeing is believing that is why I like it.

Students placed in C5, 5/14, described practical work as an activity where they are involved in carrying out demonstrations in class. A characteristic description of practical work was the response of:

Elroy: What comes to my mind is like, I think, it is like doing something in class. Like, doing demonstrations and see how things working. So that is to understand the thing more perfectly, by doing practical.

Students in School B seem to have a broader conception of practical work than what usually are practised in school. As will be recalled Lena, the biology teacher at School B, carried out mainly teacher demonstrations rather than other kinds of practical work. The re-occurring theme emanating from the students’ responses was that practical activities whether demonstrations or other kinds of activities, gave them the opportunities to practise and develop basic practical skills and abilities as well as to deepen their conceptual understanding about what they were observing.

Observation is theory-dependent and is not a passive activity. It is dynamic and involves the checking of what is perceived against one's expectations. For example, sometimes students do not see what the teacher wants them to see. Students' personal theory may sometimes influence the way they perceive what they are observing (Gunstone, 1991). In general, students have inferences that they draw from observations and these in turn are influenced by their personal theories. In my view, what is observed by a student in a group should not be generalized to the whole group. Students do not see the same things in what they are observing. In important point to consider is that: (i) teachers need to assist students to gain knowledge of and comprehend the nature of observation; and (ii) arrange for subsequent discussions to help the students to realize the effect of their own theories on their observations (Millar, 1991). He notes that:

> Learners cannot observe everything. We need to be selective and this selection is inevitably guided by the theory or theories we hold about the thing we are observing and the observation task itself (p. 48).

Observations also have advantages, pitfalls and problems. For example:

- Observations are theory laden or theory dependent.
- Not observing something does not indicate that the student lacks the relevant theoretical knowledge.
- Observations are rarely pure and never simple;
- Observing of the same phenomenon may be perceived in different ways by different students, i.e. people see through their theories or worldviews (Baird, 1995; Driver et al., 1994; Gunstone, 1991; Millar, 1991; Osborne & Collins, 2001).

b) Practical activities mostly liked by students

The students were also asked to indicate which of the given practical tasks they liked the most. They were asked to complete a table consisting of some of the practical activities by ranking such activities on a five point scale. Table 4.8

illustrates the frequency of students' choices in School B about practical activities liked most.

Table 4.8 Frequencies of Students' Choices of Practical Activities at School B. (N=12 students)

	Frequencies of choices of tasks liked most by students					
	Least liked 1	**2**	**3**	**4**	**Most liked 5**	**Total**
Demonstrations			/		/	2
Illustrations	//		/			3
Exercises	/			/	//	4
Laboratory work	/	/		////	////-	11
Investigations	///		//	////-/	/	12
Field trips		/	//	//	//	7
Manipulation of materials	/	////	/			6
Recording results	/	/	////			6
Discussions		///	//		//	7

The responses of the students from Table 4.8 presents a picture of what students preferred to do in practical work at School B. A scrutiny of Table 4.8 shows that investigation is on top of the list that students in School B liked most. This was followed by laboratory practical work, then field trips, discussions, manipulation of materials and recording of results. The last set of activities in a descending order includes exercises, illustrations and lastly demonstrations. Even students in School A expressed similar sentiments. The excerpts below are representative of their preferences:

> **Peter**: Investigations is like to find out more of what you are investigating.

And another said:

> **Werner:** Investigations makes you feel like you know. It is interesting.

Investigations are an important aspect of practical work which seems to be neglected in schools. The students in School A indicated that they had not done investigations at the time of data collection but they have conducted some projects in the previous grades. For example, **Willy** responded to reflective interview questions as follows:

R: If you are given an opportunity to carry out an investigation will you do it?

Willy: Yah. In grade six, I took part in the young scientist competition. Me and my cousin have a study on leukaemia. In the first competition we came second and in the regional competition we came first. Then the last competition at the national level, we got bronze.

R: You said that you did something on leukaemia?

Willy: Yah

R: So, what did you learn by doing that?

Willy: It was interesting. And is a lot of hard work. At first I didn't have a partner. So, we did it like two or three weeks before the first competition. So we actually have to push in everything. And at the first competition, maybe you miss something, maybe you need more statistics. We didn't have statistics in the first one. And in the second one, it was perfect. Is like, you learn everything on the way. You know why this happens or what kind of cells are these. We even have slides to show the different leukaemia cells.

Another student, **Conny**, has this to say about investigations:

R: Have you ever conducted an investigation?

Conny: Yah, the last biology project we had was in grade nine and it was about trees to get samples of a bark and leaves and stuff like that from indigenous trees.

R: What was difficult in conducting a project like that?

Conny: Getting the trees.

R: Getting the trees. What type of trees did you work on?

Conny: I mean indigenous trees. Things like the Acia tree and stuff. Actually I still remember.

R: So after getting the tree, what did you do with it, transplanting it or what?

Conny: No. You just have to go look for the tree and you have to get information about it and then you have to collect seeds and pods and leaves and stuff.

R: About this particular tree?

Conny: Yah about the particular tree. And I have to do five trees and I remember I thought I could find them easily. I thought let me at least find the trees first and then find the information and I run out time. And then I couldn't find the information.

R; So, that was the difficult part?

Conny: Not finding the trees. Yah because it was some tree were like in season. So you couldn't pick them because you couldn't have the leaves or stuff because there were no leaves on the trees. And she [the teacher] really wanted the leaves.

R: How did you go about getting these parts of your tree?

Conny: I bought some of them from nurseries. I couldn't get everything because some of trees in the nurseries were still few. I couldn't get proper bark and other different stuff and then I got some Acia trees. So bought them and got some information from them.

R: Did you enjoy doing that?

Conny: I am not sure

R: About the trees and the project?

Conny: It was hard and it was really inconvenient. Knowing things but getting them was inconvenient. You don't look like knowing that much. You just feel like you have too much work.

R: So you didn't really like investigations?

Conny: No

R: Because of what?

Conny: Not finding things

R: Can I say that that frustrated you somehow?

Conny: Yah [*nodding her head to show agreement to what I said*].

However, in school B none of the students indicated that they conducted investigations in previous grades although they had a high interest in investigations. It is apparent from the interview excerpts that the students enjoyed being involved in investigations at a project level although they were frustrated by the work load that went along with it. The following observations can be summarised from the excerpt above: (i) although the activities seemed to be enjoyable, they were difficult to complete at the end and students acquired relevant scientific information; (ii) it provided the students with the opportunities that were otherwise not available in normal lectures to deepen their scientific knowledge on some content of biology; (iii) it is a worthwhile practical activity that exposed the students to variety of practical skills such as the use of statistics, planning and designing of investigations, and presentations of results in efficient ways; (iv) there is no one way of carrying out investigations but the students tended to gain relevant skills while completing the investigation; (v) investigation activities provided the students with the opportunities to acquire practical skills both tacit and explicit skills; (vii) the activities seemed to be simple but getting relevant information seemed to frustrate the students easily; (viii) when the students went through such difficult activities they might lose interest because the investigations might be too hard and might leave the students feeling that they knew very little about what they were doing.

The students at school B showed high interest in the investigations and laboratory work and less interest in illustrations and teacher demonstrations. Discussion and field trip activities seemed to be coming out very strongly with students at School B. In order to provide more information about why the students enjoyed some of these practical activities, I interviewed some of the students randomly at School B. Some of their views are presented below:

Beverly: Investigations you can learn a lot from investigations.

Cecilie: With investigations we just go deeper into practicals. We explain and find more things.

Eluyno: If you are not sure about things you can go on the Internet and look it up.

Roxanne: When we investigate things is really like …to go in things and talk more about it; find out if I have something that I really didn't know about.

Zandré: Investigations is interesting because then you build up more knowledge when you go out into the public or to library to find out more about certain things as a given task and assignments when you are told about a certain thing and you as a student should find out more about it. You go in detail, deep in that thing that you should know about.

Based on the excerpts above as well as the students' responses depicted in Table 4.8, the following summary statements seem apposite:

- Students in the study tended to acquire scientific concepts in detail when they carried investigations.
- They tended to develop a deeper understanding of science concepts that might not have been known before conducting investigations.
- They seem to be encouraged to use a variety of information media e.g. the internet in order to gather data on issues that they were not very familiar.
- Studying issues that were unknown to the students tended to become a significant part of their investigations.
- Students generally liked to be involved in investigations and laboratory work.
- Students especially those involved in this study did not seem to like teacher demonstrations although Lena preferred to use the approach.

A closer examination of how practical work was practised at the two school sites revealed the following information: (1) students at school A were more interested in laboratory work compared to the students at School B who were interested in carrying out investigations as part of their practical work; (2) the students' second interest in School A relates to discussions (i.e. before, during and after the laboratory session) while the students in School B expressed interest in laboratory work; (3) the third most enjoyed practical activity at School A was field trips while School B students seemed to enjoy discussions and field trips as well as manipulation of materials and recording of results.

A further analysis of the data revealed that practical activities were enjoyed to some degree by the students in the two schools. For example, some students in School A indicated that they enjoyed discussions for the following reasons:

> **Joao**: I like discussion the most of all because you can communicate – use more people more heads are better that one. So if you discuss one can like argue and solve problems quicker.

Joseph: Discussions also help because usually when you do it alone you do not know how it is done.

Peter: Sometimes you are not sure of the results then it is nice to discuss.

Like their counterparts in School A, the students in School B also indicated that discussions assisted them to carry out practical work properly, interpret results and convince one another in understanding science concepts. The following excerpt is representative:

Eluyno: Discussions we are doing it as a group. So you also get opinions and learn from other students. Maybe they might give you some information that you didn't know.

Practical work in general is not self-explanatory. Most of the time students might see things that they want to see even if these are not observable (Millar et al., 1999). In other words, seeing is not always the same as believing. They maintain further that in most cases the students might fail to produce the phenomena, patterns, trends and explanations about what they observe. Another student in School B also said:

Charles: If I have a problem about something I really like to go to people and then get a better view or understanding about that.

In support of the above notions from students, Solomon (1994a) suggests that discussions (pre-laboratory and post-laboratory) could be important in that the students might get second opinions from other students, assist one another to complete practical tasks in time and make sure that they are on the correct route and not deviate from what they are doing.

As can be recalled, Lena the biology teacher at School B carried out teacher demonstrations without providing opportunities for discussions of results or any other anomalous results. The re-occurring theme emanating from the students responses is that discussions give them the opportunities to gain and learn from one another. As they listen to others they tend to develop a better view or understanding of certain phenomena. This view accords with Solomon's (1994a) view about the purpose of group discussions in practical work and she indicated that discussions have value for different purposes such as: (i) giving students the opportunity to negotiate meanings; (ii) providing the opportunity to assist or tutor one another; (iii) helping students to construct knowledge at a social level.

From the classroom observations, it seemed evident that Lena denied her students valuable opportunities for the construction of knowledge at a social level as well as allowing herself to diagnose their' misconceptions or alternative conceptions (Driver et al., 1994). She did not provide the necessary for opportunities for discussions during the teacher demonstrations or even devote a special lesson for such a purpose. This observation is in agreement with Solomon's (1994a) findings that teachers' preoccupation with the protocols of demonstrations often prevents them from giving sufficient opportunities for discussions critical to their conceptual development. Lena could have decided to follow the austere prescription of being neutral and not trying to influence students' observations. In general, discussions are essential because teachers and students use words and gestures that may suggest new meanings to others. In addition, discussions help in the planning and design stages of practical work as well as in sharing personal perspectives on the topic under discussion.

Fieldtrip is another activity enjoyed by the students in both schools. The students in School A have been on field trips during the previous years when they were in grade 10 but they had not been out at the time of data collection. Here are some of the students' comments from School A:

> **Sam**: Because we have to go out. It is something different from the classroom. In the classroom throughout the year is a little bit boring, is always the same things.

> **Ben**: Is like when we go out and we learn more and is much better to see something rather than learning it on paper or books. For me, I can see and learn better when I can see it.

Sara: I like fieldtrips because I like being in nature but we have not done it this year.

Jacob: I myself like going out, working outside beyond the classroom or whatever. I think it is easier for a person to understand something once it has been seen it.

Lena's students in School B also took part in field trips in the previous grades but not at the time of data collection. Here are some of their comments:

Cecilie: With fieldwork you get to see how the stuff is done.

Eluyno: I like it when we go on trips so that we can see how things look like, how they make chocolate, for example, how do they produce it and put it in packages

Harrian: I like fieldwork because you go out and see how things are done, that is, you experience at first hand.

Further, Lena's students stated that fieldtrips gave them opportunities to learn things beyond the classroom. The following summary is derived from their expressed viewpoints about fieldtrips:

- Acquisition of knowledge and understanding about what living organisms look like and how they interact with one another;
- Development of knowledge about how some organisms are used in the production of some food such yoghurt and chocolate;
- Acquisition experiences through first hand information by observing how certain materials are produced;
- Enjoyment of what they learnt during the trip.
- Opportunities to get away from boring theoretical lectures.

Woolnough (2000) remarked that investigations could best be described as lying on a continuum rather than being seen as a separate practical activity and that under such a continuum, investigations take many forms such as open against closed activities as well as directed and structured as opposed to undirected and unstructured practical activities. The teacher may arrange activities that involve students in tackling real problems, for example, the study on leukaemia conducted by Christie's students in school A. Such a practical activity will pave ways for students to learn scientific methods. This view accords with Ntombella (1999) who concluded that students will not only focus on a uniform method or procedure but will begin to value the role of varied approaches, imagination, planning, confirmation and instrumentation in the pursuit of scientific knowledge. Investigations can have a number of advantages in the teaching and learning of science such as:

- They can motivate students to want to satiate their curiosity.
- They tend to enhance the development of scientific attitudes among students.
- Many students who are not successful may be turned on by investigational work.
- They can be enjoyable and can lead to teamwork and co-operation in science learning;
- The teaching of content (conceptual understanding) and process (procedural understanding) can be geared towards an investigation as the end point or motivator (Toh, 1991).

Students who are involved in investigations might also perform high-order tasks such as control of multiple variables but might be unable to make them explicit in later interview/discussion sessions (Toh, 1991). According to White:

> Repeated experiences teach you how to behave in the laboratory. They give you familiarity with chemicals and apparatus and with abstract concepts. They can also teach the fundamental principle of scientific methods of holding all variables but one constant in order to see the effects of that one.

> Repeated visits to the laboratory transmit an impression of science and have a strong influence on attitude to science." (p. 81 - 82).

4.2.4 Pitfalls and problems associated with investigations

But as has been shown in a plethora of research reports on investigations, investigational activities carried out by students are by no means free of problems. The points below are representative of such problems:

- Little agreement among teachers of what is an investigation or experiment in that both activities are in a continuum rather than separate activities.
- The extent to which the teacher should intervene;
- How to deal with incorrect answers to closed-ended investigations;
- Planning is one of the most difficult aspects for the students doing investigational work;
- It rarely reflects the complexity of the true nature of science (Baird, 1995; Hodson, 1991; 1996b; Parkinson, 1994; Toh, 1991; Wu & Krajcik, 2005)

It is, however, important for students not only to visit the laboratory but also to have a purpose and a need to be engaged in what they do and reflect on what they are doing. The next section deals with the teaching strategies used in preparing students for practical examinations in the two school sites.

4.3 What types of instructional strategies do the Biology teachers use to prepare their students for the practical examination?

> Teaching science involves introducing the learner to the social language of school science. The teacher is central to this process, as they take the role of an interpreter, or a mediator, of the school science social language (Mortimer & Scott, 2003, p. 17).

In this study, the flow of classroom interactions focuses on three aspects of classroom discourse: the nature of teacher intervention, the form of teacher utterances and teacher actions in the flow of the discourse as described in Chapter

3, section 3.4.1. Table 4.9 describes the categories of teacher-student interactions observed in the study.

Table 4.9 Categories of teacher-student interactions

Teacher's Activities Category		Descriptors of activities
Teacher actions in the flow of discourse		
1	Practical skills	1. Manipulates materials/ apparatus 2. Makes measurements 3. Reads instructions 4. Follows instructions
2	Carry out demonstration	5. Uses real specimen/materials 6. Prepares solutions just before starting with demonstration 7. Carries out the activity
3	Provides assistance to students	8. To carry out an activity 9. To take measurements 10. To carry out an activity in a small group
Forms of utterances		
4	Describes what to be observed	11. Event, phenomena 12. Patterns 13. Remarks about what should be observed 14. Content, apparatus and materials used
5	Explanation provided	15. About an event, phenomena 16. About the procedures to be followed in completing a task 17. About a procedure in taking measurements
6	Opportunity provided to	18. Make and record observations 19. Complete a table 20. Make and record measurements/estimates 21. Discuss results/ anomalous results
Nature of teacher interventions		
7	Shares ideas	22. Science content or procedural information 23. Repeat an idea 24. Share group/student's findings 25. Asks students to prepare or complete a table, a graph 26. Reminds students about safety precautions, format to write report
8	Selecting ideas	27. Work on ideas 28. Developing the scientific story
9	Shaping ideas	29. working on ideas 30. developing a story
10	Marking key ideas	31. working on ideas 32. developing a story
11	Checking student understanding	33. probing for meanings 34. probing a specific group for meanings 35. checking on continuity
12	Reviewing	36. returning to and going over ideas

Different classroom settings were observed in order to provide some insider stories into what happened in a normal classroom as well as laboratory classes in school A and B. As observed, all the three teachers at both school sites provided lectures. In addition to lectures, Christie and Jarijo exposed their students to group practical work while Lena exposed her students to teacher demonstrations. The teaching and learning activities focused on the following Biology topics:

- Nutrition
- Nutrients
- Leaf structure

- mineral requirements
- Food testing laboratory activities
- Different laboratory activities on factors affecting photosynthesis.

In this section narratives were used to present learning conditions that prevailed during instruction. In order to provide a comprehensive report about classroom/ laboratory conversations that took place between the teachers and the students as well as amongst the students themselves. Many attempts have been made to compare directly the impact of small group practical work and demonstrations however not much differences were noticeable (Harlen, 1999). Thus, laboratory activities are reported according to the work conducted by teachers during their lectures and amongst students in small groups and teacher demonstrations as instances of pedagogical strategies in relation to the two school sites.

School A

Christie and Jarijo taught under more favourable conditions with considerable number of laboratory equipment such as 30 bio-viewers, 10 simple biological microscopes, 5 dissecting microscopes, 15 hand lenses. Each laboratory at school A has appropriate sitting places ranging from 15 to 21 students' working stations. As indicated in Chapter 3, there were five long benches and there were three well-arranged working stations at each bench, each with a tap, a small rank where tubes could be kept, a fixed gas tap to hook on a Bunsen burner, several glass containers, wood rod test tubes holder, droppers or plastic syringes, several tripods, tiles at least for every working station and different chemicals depending on the activity. In addition to the fifteen working stations with typical laboratory high chairs, the big laboratory has six extra working stations arranged alongside the laboratory walls. The condition that prevailed at school A provided both Christie and Jarijo with the opportunity to involve their students in student-centred activities (Walczyk & Ramsey, 2003) that were done in small groups. Overall, the laboratories at school A were well-maintained and well-resourced.

At school A, Christie and Jarijo used laboratory manuals for teaching. Christie and other senior teachers developed the laboratory manual booklet for their students. They used past examination papers and various Biology textbooks to write the laboratory manual. Most of the activities in the manual focused on developing practical skills such as: following instructions, observing events, recording results quantitatively as well as qualitatively, deducing conclusions from what they have observed and answering a range of selected questions both theoretical and practical as observed in section 4.2.2. Both Christie and Jarijo at school A used the laboratory manual as a spring board for their lesson plans. In other words they did not have extra lesson plans except the teaching manual.

On the whole the laboratory/classroom environments differed in many ways in relation to the support that was provided in terms of the instructional practices observed, the setup of the laboratory or the classroom and the intellectual development were encouraged. In some instances, teachers' talks dominated the discursive interactions while in others students controlled the flow of the discussion.

The next section analyses and discusses single instances of emergent themes in the scripts of the lectures, group experiments and teacher demonstrations. Some teachers structured their teaching around a practical activities or homework questions or they let students carry out practical activities in group experiments. Thus, different episodes of lectures and practical activities were used to present the nature of teacher interventions, the form of the utterances and the types of actions that took place in the flow of the discourse as described in Chapter 3.

4.3.1.2 Lectures

Christie, Jarijo and Lena taught biology practical work in different ways. All three teachers presented pre-practical lecture-lessons that were followed by practical sessions.

Sometimes the lectures focused on teaching theoretical science knowledge while at other times the teachers focused on experimental activities and safety precautions that students must know before taking part in hands-on practical activities. In some instances, lectures were based on providing correct answers to given homework questions. The questions for homework assignments where sometimes based on questions taken from past practical examination papers. The current examples of episodes were taken from some of such lessons. Although the teachers indicated that they discussed practical work results with their students after completing the tasks, none of them held post-practical discussions.

Episode 1: A test to show that leaves can make food.

This episode was taken from one of Christie's theoretical lessons. She was teaching her students about how a leaf was adapted to producing food. At the beginning of the lecture, the students came in the classroom and sat quietly at their desks. Christie started teaching and focused on the adaptations of leaves for the production of food (photosynthesise). Christie taught by question and answer method and the episode below is one such a teaching moment. After teaching for some time a student initiated the following discussion:

Ben: How can chlorophyll change the carbon dioxide to the carbon in order to make food in the chloroplast?

Christie: When we come to the detail of the process of photosynthesis then we can discuss what happens. But now we are interested in is the structure of the leaf, how it is adapted to be able to make food. Because I want you to proof that the leaf makes food. I got all these wonderful statements and theories and discussions of the adaptations of the leaf why it should be able to make food. The previous chapter we discuss through tests, we said the product of photosynthesis is glucose. It must be glucose? What test did we do?

Laili: Benedict …

Christie: Benedict test. What did you mix with the Benedict?

Laili: Benedict solution

Christie: Benedict solution and ….?

Lea: water, iodine

Christie: No. How did you perform the Benedict test to proof that there is sugar in the leaf?

Tutu: acid

Christie: Acid. Why?

Laili: to release the glucose

Christie: Ok, you want to release the glucose inside it. So what is so typical around each plant cell?

Maria: Cell wall

Christie: and then…?

In analysing episode 1 above, it became clear that the types of actions taken by Christie and her students during a lecture differed from their actions when they conducted practical work in the laboratory. In terms of the 12 aspects of the framework provided (see Appendages P and Q), the main themes emerging from episode 1 are summarised in Table 4.10. For ease of reference, it is apposite to indicate what the following capital letters stand for:

- I - stands for initiation: normally through questions from the teacher but student may also pose questions.
- R - stands for response: from the student or teacher
- E - stands for evaluation: by the teacher
- F- stands for feedback (could be elaborative feedback).

Table 4.10 Episode 1: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Teacher verbal communication in terms of questions or posing further discussion about practical procedures
Forms of utterances	No description is made of what is to be observed or explanations offered. However, students were open to contribute to the discussion.
Patterns of interactions	I-R-E-R-F-E-R-E-R-E-R Chain with positive evaluation and the feedback given. Dialogue was supported to minor extend but feedback was authoritative in nature.
Forms of interventions	Sharing, selecting, shaping students' ideas , checking students' understanding and reviewing previous content knowledge or work

Table 4.10 shows that Christie's actions in the flow of the discourse in episode 1 are:

- Posing questions about practical activities her students had conducted in the laboratory.

- Referring the students to recent discussions about the adaptation of leaves in order to refresh their reasoning.
- Providing positive evaluation to students' responses.
- Negotiating meaning with the students at the social inter-mental plane by checking on students' understanding of science concepts and practical procedures as well as reviewing previous science knowledge. Other interventional strategies that Christie used were to share, select and shape the students' scientific and procedural ideas in trying to build a scientific story at the back of her questioning strategy.

Firstly, it is important to mention here that Christie's actions should not be considered as being exemplary to what is generally taking place during a normal practical session. Both Christie and her students were not involved in carrying out practical skills but merely spoke about what should have happened during practical work lessons. Secondly, as can be observed from Episode 1, Christie's utterances did not provided the room for the descriptions about what the students should observe neither did she provide deeper explanations about why certain processes needed to take place during practical activities. However, a lecture appears to provide good opportunities for the teacher and students to discuss issues related to the construction of new knowledge but not to promote the development of practical skills. Thus, Christie as a science teacher appeared to provide the necessary stimuli and appropriate social interactions in this episode better than during the laboratory sessions where the students worked through activities on their own.

The discussion in episode 1 appeared to enable the students to understand and recall what they did during the practical activities. Thirdly, Christie's seemed to apply more intervention strategies during the lecture sessions than during the laboratory sessions in episode 1. In order to improve learning, Christie needs to arrange her lesson in such a manner that can promote better interactions than was the case. Other scholars (Brooks & Brooks, 1993; Roth, 1995; Tobin, 1995) maintain that meaningful teaching and learning need to focus on the students' previous knowledge, experiences as well as the social process in order to increase students' interactions with the science content. Lastly, the pattern of interactions in Christie's discussions in episode 1 is more of an authoritative chain without any feedback given. Such a pattern of activities seems to minimize the chances of interactive discussions taking place. In this instance, Christie provided little or no feedback to the students and appeared to minimize the chance for the students to construct and internalise new information at the social inter-mental plane in the classroom (Lutz, Guthecie, & Davis, 2006; Vygotsky, 1978; Zady et al., 2002). In such cases, less guidance is provided to students (Krystyniak & Heikkinen, 2007).

Episode 2: Starch test

This episode is based on issues that could emanate from observation activities during experimental work. In this episode Christie focused her students' attention on some relevant aspects of the shortcoming of carrying planning or designing and carrying practical observations.

Christie	Ok to see the colour change because if we got a nice dark green leaf or red leaf, how can we see that there is colour change to blue-black. So we want to remove the chlorophyll, the green part and then we will be able to add the iodine to ensure that there is colour change when starch is present. How?
Lala	ethanol
Christie	She comes to a story with ethanol. Ethanol is able to extract the colour, the chlorophyll. We can also use ethylated spirit.
Lala	boil leaf in the ethanol while in water bath
Christie	Why can we just put it ethanol? Why do we boil it in a water bath?
Lala	[silence]
Christie	I want to have a motivation as to why first we boil it in hot water and then in the alcohol for a typical Namibian plant?
Maria	to remove the thick cuticle waxy layer
Christie	to remove the waxy layer. If you have to wait for the ethanol to remove the chlorophyll first you will not finish your experiment in time. First put the leaf in hot water to destroy the waxy layer then you can take it out, put it in ethanol. The ethanol extracts the liquid, the green stuff.
Ben	It becomes hard
Christie	it becomes brittle when you take it out of the alcohol.
Maria	because the alcohol will pull all the water out.
Christie	uuuhhh the alcohol take out all the liquid that were present in these mesophyll cells. So what are you left with? The hard cell walls. You roll it up in a shape together into the test tube and then you remove it.

Emerging themes from episode 2:

The themes that emerged from episode 2 are summarised in Table 4.11.

Table 4.11 Episode 2: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Teacher verbal communication in terms of questions or posing further discussion about practical procedures
Forms of utterances Patterns of interactions	Description of what is to be observed provided, explanations offered. I-R-E-R-E-R-F-E-R-F-Chain with positive evaluation and feedback given. Support dialogue interactions
Forms of interventions	Sharing, selecting, marking key ideas, checking students' understanding without reviewing previous activities or work

Table 4.11 shows that in Episode 2, Christie's actions and forms of utterance did not change much comparing it to episode 1. However, there is a change in the patterns of interactions and the nature of the interventions provided during the discourse. The pattern of interactions changed from a non-interactive to supportive dialogue interactions. As can be observed from the episode, more feedback was provided to the students during instruction and the following themes emerged:

- stating the problematic scenario that will assist the students to take a proper decision in planning and designing appropriate procedures for observational activities;
- providing information or reasons to why some procedures need to be done in order to enable the students to make appropriate observations;
- sharing an individual student's idea with the whole class and at the same time promoting meaning at a social inter-mental plane across the students;

- shaping an individual students idea by using appropriate scientific terminology across the teaching and learning environment;
- providing the use of improvised chemicals (ethylated spirit) in stead of using ethanol which more is expensive;
- posing questions in order to promote further discussion as well as to promote thinking;
- providing positive evaluation to students' responses; and
- providing scientific story behind the deed by reasoning out why it is necessary to carry out a certain step before embarking upon another procedural step.

Equally, she provided teacher intervention strategies such as sharing, marking key ideas and checking on the students understanding during the flow of the discourse (Chin, 2007; Puntambekar & Kolodner, 2005). In other words, Christie provided scaffolding strategies in order to promote meaning across the social inter-mental plane in order to allow the students to construct and internalise science knowledge (Roth 1995; Vygotsky, 1978). Christie provided positive evaluation to the students' responses. In other words, Christie led the students through joint speech activity in order to create a common knowledge among classroom members. This in turn served as a contextual basis for new understanding to develop continuously (Oh, 2005).

Episode 3 Homework questions

The episode was taken from lecture conducted by Jarijo and is based on homework questions. In this episode, Jarijo centred her discussions around homework questions in order to establish teaching moments. It is the first period after the break of 30 minutes and the students were really excited and noisy. Jarijo waited for them to settle down and some the students, who were late, needed to tell Jarijo why they were late.

Jarijo	The first thing you need to do is to take out your practical manuals. [Ok. Let us start quickly. The test for starch. You have to answer those questions for me. Question 1: Name three reasons why you needed to put the leaf in boiling water. Charlene?
Judy	You need to soften the cuticle and the epidermis layer.
Jarijo	You mmmmmm
Dawid	and need to destroy any enzymes.
Jarijo	mmmmm
Gustav	Need to destroy the cell wall and cell membranes.
Jarijo	Excellent. What else?
Gustav	Chloroplasts.
Jarijo	So, you said you must destroy the cuticle and the upper epidermis, you have to destroy the cell walls and cell membranes,
Gustav	and the chloroplasts.
Jarijo	and the chloroplasts to give the colour off so that you can see the reaction with starch, right? And then you have to destroy….the heat will destroy the enzymes that could have broken down starch. All of these are destroyed, right.

Emerging themes from episode 3:

The themes that emerged are summarised in Table 4.12.

Table 4.12 Episode 3: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Actions were based on homework questioning that provided a scenario to discuss related practical procedures. No skills were practically performed.
Forms of utterances	No description is made of what is to be observed. Explanations were offered.
Patterns of interactions	I-R-E-R-E-R-E-F-Chain with evaluation and few feedbacks information given. Authoritative interactions
Forms of interventions	Checking students' understanding without reviewing previous activities or work

Table 4.12 shows that Jarijo's actions were not practically performed but verbal communication took place in order to groom the students into practical endeavours. Such knowledge, for example, knowing why one needs to boil the leaf before carrying out the test, will assist students to be able to plan similar practical activities. There is considerable evidence that suggests that familiarity with the context of a task influences the extent to which particular strategies are used (Millar & Driver, 1987). Furthermore, Jarijo's forms of utterances focused

on providing explanations to students on why some practical procedures needed to be conducted in a particular manner. Lastly, Jarijo's roles in providing scaffoldings and mediating learning through verbal interactions involved the following themes:

- using non-verbal communication skills in motivating the students and probing them to provide appropriate answers;
- providing reward in terms of praising the students when they provide good answers;
- probing students to provide more answers to questions given in their homework;
- sharing answers provided with the whole class by summarizing the answers to the question; and
- providing reasons on why some practical procedures need to be conducted with the whole class.

Verbal communication seems to be important as much as practically performing the activity. Each word spoken or written carries meaning that needs to be mediated to students (Nakhleh et al., 2002; Oh, 2005; Roth 1995; Staver, 1998; Tobin et al., 1994; 1995; Vygotsky, 1978). Furthermore, Tobin (1995, p. 302) maintains that "teachers' role is to mentor student understandings and guide discussions so that students have opportunities to put language to their understandings and to engage in activities". Jarijo likewise Christie also shared information with the students at classroom level and allowed her to debate and negotiated what need to be learnt (Hodson & Hodson, 1998a; Richardson, 1997; Roth, 1995). She also provided positive evaluation to the students by providing rewards in a form of praises. Such practices seemed to motivate the students to participate more in classroom interactions and "knowledge moves from the inter-mental plane to the intra-mental plane, that is, from social to psychological" (Richardson, 1997, p.27). In this episode, Jarijo seemed to provide little feedback to the students and that in itself establishes an authoritative interaction in the classroom where she was in control of the interactions rather than focusing on establishing a student-centred approach where the students are more actively involved in leading the discourse (Roth, 1995).

Episode 4: Homework question 6

Episode 4 is taken from a lecture about factors that limit the process of photosynthesis to take place. This lesson was a follow-up presentation after Jarijo had taught how the leaf was adapted to produce food. Episode 4 was taken from the middle of the presentation and reads as follows:

Jarijo	Describe in detail exactly how you would modify this experiment to test for light intensity. It is happening at low light intensity and high light intensity. What do you think?
Kerstin	I have to explain the whole procedure?
Jarijo	Yes, you have to explain the whole [*putting stress on the word whole*] procedure.
Class	No, mmmmm…. is too much [*in a choir*].
Jarijo	Yes, now you have to modify it. What would you do to test for high light intensity and low light intensity? What would you do?
Jessika	you take two plastic bags and two plants, and…
Jarijo	Light intensity?
Jessika	Mmm no. you must check how much carbon dioxide is used from one plant put in light and other at a shadow.
Jarijo	Yes. Ok, you are going ahead with it.
Jessika	you take two different plants and you put one in direct sunlight
Jarijo	Yes
Jesika	and the other one at a place where there is light but not a lot.
Jarijo	yes
Jessika	and then it tend to slower the rate.
Jarijo	Yes slower intensity
Jessika	and then measure the rate of photosynthesis.
Jarijo	rate of photosynthesis. Yes. How?
Jessika	measuring the starch.
Jarijo	How do you measure?
Ben	measuring the plant [*another student screamed from the back*].
Jarijo	you test for starch. You test the leaf for starch. Isn't it?
Saara	mmmm
Jarijo	and then you look at the colour in which leaf is dark to show that there is more starch. You will test for oxygen but it will be difficult because you will need a water bath. That's why I said to test for the rate of photosynthesis is very difficult.
Saara	that's a fact.

Emerging themes from episode 4:

The themes that emerged from episode 4 are summarised in Table 4.13.

Table 4.13 Episode 4: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Actions were based on homework questioning that provided a scenario to discuss related practical procedures. No skills were practically performed.
Forms of utterances	No description is made of what is to be observed. Explanations were offered.
Patterns of interactions	I-R-E-R-E-R-E-F-Chain with evaluation and few feedbacks information given. Authoritative interactions
Forms of interventions	Checking students' understanding without reviewing previous activities or work

Table 4.13 shows that Jarijo's actions in the flow of the discourse were mainly conducted in a verbal manner. Again no practical procedures were described or explained to the students. In this episode, Jarijo has changed the patterns of interaction as well as the forms of interventions. However, Jarijo provided the descriptions of what were to be learnt. The following themes emerged from this episode:

- provision of reasons and information on why Jarijo needed to teach the topic about limiting factors;
- probing students for more information;
- provision of positive evaluation by describing scientific terminologies and providing information about the application of knowledge to everyday practices;
- at times overloaded the students with questions – no wait-time was provided;
- negative response was given due to lack of appropriate information.

As can be observed from Episode 4, Jarijo seemed to provide a lengthy feedback with elaborated explanations to the students in a motivated manner. Such a practice appeared to provide less room for debating between the teacher and the students. In other words, the context appeared to be moving into a traditional approach rather than a student-centred that was likely to nurture the negotiation of knowledge at the social inter-mental plane. Equally, Chin (2006) posits that the "IRE" pattern of interaction takes place in traditional classes and induces low cognitive level thinking as well as to minimize the role of the teacher in the co-construction of meaning. I have also concurred with Zady et al. (2002) who said that the manner in which the teacher controls the pattern of interactions might influence the learning environment as well as the type of teacher intervention strategy in scaffolding meaning-making at the social inter-mental plane. In this episode, Jarijo at times overloaded the students with questions when probing for information. Such actions tend to discourage the debate between Jarijo and the students unlike Chin (2007) who observed that teacher questioning stimulates productive thinking in constructing knowledge and Tobin et al. (1994) who maintains that enough wait-time provides students with an opportunity to reflect on what is discussed or to transfer control from person to person within classroom discourse. As it can be observed from episode 4, the students did not respond when Jarijo posed more than one question at a time.

Lena

Episode 5 is taken from Lena's theoretical lessons on limiting factors at school B. the episode forms a part of the first section of the lesson and includes greetings exchanges between the Lena and her students. Lena's approach to teaching the topic was very much different from how Jarijo taught the same topic to her students in school A.

Episode 5 Limiting Factors

Lena	Good morning
class	Good morning Ms
Lena	Now we will talk about limiting factors. I gave you work yesterday on limiting factors. [she wrote on chalkboard]. So tell me what did we say the rate of photosynthesis is?
Harrian	How fast the process will take place.
Lena	Yes how fast the process of photosynthesis will takes place. Now what do we understand by limiting factors?
Beverly	Something that determines the rate…
Lena	Yah something that will determine how fast or slow the process will take place, ne. Now what are the limiting factors that limit photosynthesis? First you list that.
class	[silence]
Lena	Give me the limiting factors.
Zandre	Temperature
Lena	Charles?
Charles	carbon dioxide
Lena	availability of carbon dioxide, ne.
Amy	availability of carbon dioxide [students repeated after her].
Lena	Gabriel?
Gabriel	[silent]
Lena	Where do we go from here?
Harrian	Light intensity
Lena	The last one?
class	silent
Lena	The availability of water. Ok you first re-cap, ne. Let us start now with [show to the availability of diffusion on chalkboard] What is the process?
Zandre	Diffusion
Lena	Yes diffusion. Ok, and water
Charles	from the soil
Lena	from the soil. What is the process?
Amy	osmosis
Lena	osmosis. Ok what do we understand by light intensity?
class	silent
Lena	Where does the light come from?
Charles	the sun

Emerging themes from episode 5:

The themes that emerged from episode 5 are summarised in Table 4.14.

Table 4.14 Episode 5: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Teacher responded in verbal manner; no practical activities were conducted.
Forms of utterances	No description is made about what is to be learnt. No explanations were offered.
Patterns of interactions	I-R-E-R-E-R-E-F-Chain with affirming evaluation and few or no feedback information given. Authoritative interactions
Forms of interventions	Shaping students' ideas, reviewing previous work and posed questions to recall information.

Table 4.14 shows that Lena's actions in the flow of the discourse were mainly conducted in a verbal manner and she also used the chalkboard to provide more text and diagrams about the topic. However, Lena provided no descriptions of what was to be learnt and no explanations or feedback was given. The pattern of interactions that emanated from this episode was authoritative in nature and contained a typical 'I-R-E-R-E-R-chain' of interactions. The following forms of teacher interventions emerged from this episode:

- reviewing previous work that was taught;
- shaping students' ideas by adding more information to what they said;
- posing questions – mainly at the re-call knowledge level;
- sharing students' ideas to whole class by using semiotics in the form of diagrams representations;
- providing responses in monologues – phrases or scientific terms are used;
- probing when there was silence by calling upon a student.

Firstly, the pattern of interactions is restrictive and does not allow much dialogue between the Lena and her students. Secondly, questions were posed at the lower level of understanding – recalling of knowledge and were closed-ended rather than open-ended questions. In other words, the students were expected to know the answer or not. Thirdly, Lena's responses were presented in monologue in this episode, that is, she did not elaborate on students' answers. Fourthly, Lena preferred to call her students' by names in order to respond to her questions. Such a situation appears to reduce the channel of communication between Lena and her students. In addition, it also tends to restrict the debate that could help in establishing shared meanings at the class level. This appears to be in disagreement with Tobin's et al. (1994) view that the provision of clarity about content assists in mediating learning. Lastly, Lena like Christie and Jarijo, shared and reviewed previous work with all the students. Emanating from the foregoing discussion is that, it seems that the lack of multiple forms of support and multiple learning opportunities (Puntambekar & Kolodner, 2005) may lead to poor teaching and learning context where active multiple forms of meaning-making strategies are minimized. In other words, a dynamic complex teaching and learning environment should offer multiple support tools or agents in accordance with Puntambekar and Kolodner's (2005) position that there is a need for distributed scaffolding approaches in offering support to students' emerging understanding.

Episode 6 Enzymes

Episode 6 is taken from Lena's theoretical lessons on the topic of enzymes at school B. Episode 6 forms a part of a section of the lesson. Lena's approach to teaching the topic was very much different from the way Jarijo taught the same topic to her students in school A. Class refers to a group of the students who answered in chorus.

Lena	So we will look at the enzymes. What is the definition for enzymes?
Amy	Enzymes?
Salmi	must be effective in reacting with ….
Harrian	one enzyme will affect the rate of something which is reacting on.
Lena	Is that the definition?
zandre	the substance that speed up another reaction.

Lena	it is a protein which acts as a biological catalyst. One of the functions of the biological catalyst is to speed of the reaction. Here you want to say chemical reaction without taking part in that reaction. What do we call all the chemical reactions in the human body?
Charles	metabolism
Lena	Metabolism and there are two chemical reactions, that is anabolic and
Lea	Catabolism
Lena	catabolic reactions? Now what happens in animals in an anabolic reaction?
Class	silent
Lena	Large complex molecules become small molecules. So what is needed for the smaller molecules to become larger molecules?
Eluyn	energy?
Lena	Energy. Energy is now in the form of…?
Elauyn	ATP
Lena	Yesterday I asked you to find out what ATP stands for.
Harrian	I am not sure how to pronouns it but is adenosine triphosphate, correct?
Lena	ATP stand for Adenosine triphosphate. I will tell you more about ATP when we will do respiration. Now what happens in catabolic reactions?
Lea	The reactions where complex molecules break into simple molecules.
Lena	Now we break up larger components to smaller [writes an arrow on chalkboard]. So what is this?
Class	energy (choir)

Emerging themes from episode 6:

The themes that emerged from episode 6 are summarised in Table 4.15.

Table 4.15 Episode 6: Analysis of teacher-student interactions during a lecture

Actions in the flow if discourse	Teacher responded in verbal manner; no practical activities were conducted. Used diagrams in teaching.
Forms of utterances	Description of terminology given. Explanations were offered.
Patterns of interactions	I-R-E-R-E-R-E-F-Chain? with evaluation and few feedbacks information given. Silence within the patters of communication. Authoritative interactions
Forms of interventions	Shaping, questioning and reviewing previous activities or work. Diagrams used.

Table 4.15 shows that Lena’s actions were mainly conducted in a verbal manner. She also used diagrams and arrows to represent scientific information about the topic in Episode 6. However, Lena provided no descriptions of the terminologies about the topic and no explanations or feedback was given about the scientific

meanings embedded in these terms. The pattern of interactions that emanated from episode 6 was authoritative in nature and contained a typical 'I-R-E-R-E-R-chain' of interactions where silence incidents appeared in the pattern. The following forms of teacher interventions emerged from this episode:

- probing further students' involvement by using close-ended questions;
- sharing ideas by repeating students' ideas to the whole class;
- shaping students' answers by providing more content knowledge to the whole class;
- reviewing previous knowledge about what was taught; and
- using tools such as diagrams and arrows to add meaning to what is being taught

There is little change in Lena's interventional strategies in this episode as compared to episode 5 in the pattern of interactions, the questioning strategy, the responses given to the students, the use of tools and the occurrence of silence in the middle of the presentation.

In summary of the lecturing episodes 1 to 6, one aspect that needs to be taken into account is that single incidents are analysed and that such incidents differed from teacher to teacher in clarity, statements and coherence (Morge, 2005). However, these episodes provide a platform to analyse and discuss the types of teacher intervention strategies that were provided and how these strategies seem to assist the students to construct debate and negotiate scientific knowledge at a social plane. During lecturing, multiple forms of support and learning opportunities were provided rather than distributed scaffolding approach that tended to support hands-on inquiry learning (Puntambekar & Kolodner, 2005; Shepardson & Britch, 2006). From an examination of the six episodes, it became clear that in most lecturing sessions the three teachers communicated to their students in a verbal rather than in a practical manner. Christie and Jarijo used open-ended questions to initiate discussions with their students. The nature of the questions asked by Christie and Jarijo to promote discussion with the students centred on practical work routines rather than on the content.

Furthermore, the form of utterances that was not used by all three teachers neither captured fully what happened in the practical sessions nor provided adequate explanations for such episodes or indeed explained why certain procedures should be followed. Likewise, none of the three teachers offered opportunities during lectures to demonstrate how certain experiments were set up or carried out. Lastly, there seemed to be a link between the pattern of interactions and the nature of teacher intervention. Christie lectured in an interactive way, while Jarijo and Lena lectured in an authoritative rather than an interactive manner.

Although lecturing seems to provide more room for multiple zones of interactions the nature of teacher intervention could be restrictive in a way. For example, a teacher might share information from an individual student with the whole class as was the case in Episode 2 where Christie shared the information about ethanol supposedly meant for a student with the whole class. On the other hand, Jarijo and Lena using authoritative forms of interactions communicated less with the students and presented lectures in a monologue. Both Lena and Jarijo seemed to offer little in promoting mediation in learning, scaffolding in meaning-making, negotiation of meanings and debating meaningfully in order to construct knowledge in an active manner (e.g. Chin, 2006; Liang & Gabel, 2005; Puntambekar & Kolodner, 2005; Windschitl, 1999; Wu & Hsieh, 2006). The next section will deal with student-student interactions within group experiments.

4.3.1.3 Laboratory activities conducted in small groups

In the constructivist perspective, learning is a process of active construction of knowledge. The students' meaning-making is located in their activities which are purposeful, social and cultural. In this perspective, the students construct new knowledge as they take part in discussions at both social and individual levels. Such discussions often consist of different forms of discourse as well as practical tools in the science community (Mortimer & Scott, 2003; 2000; Zady et al., 2002).

Group experiments in Practical work

In group experiments students are communicating with one another and to some extent, they might also interact with their teachers. The structure and the organisation of the group might differ from group to group and might also be affected by the classroom environment. Learning in science classes is a process of active engagement in the construction of scientific knowledge and skills as well as in using science tools. Such learning does not take place in a vacuum but meaning-making is negotiated socially and culturally as well as through the medium of language (Hodson & Hodson, 1998a; Nakhleh et al., 2002; Richardson, 1997; Roth, 1995; Staver, 1998; Zady et al., 2002).

In analysing the learning instances within given episodes, it was found that the patterns of interactions, the organisation of duties, the participation in tasks and negotiation of meanings differ from group to group as well as from one practical activity to another.

Episode 1: Testing a leaf for starch

In Episode 1 the students focused on testing leaves for the presence of starch. The students supervised by Jarijo, worked on a group experiment in the biology laboratory. The students used laboratory manuals to complete their practical activities. They interacted with one another as well as with the subject content to complete the various laboratory tasks. Below is an example of teachers' and studnets' verbal and no-verbal interactions within a group:

Mara Where are matches?
Judy Here.
T Start with the hot water bath.
Mara The stick? [referring to the leaf]
Judy No
Dawid Are you scared?
Judy Ooouugh…[lights the Bunsen burner] yes I am very scared. How can I light up this thing?
T Do you know exactly what you supposed to do?
Judy Yah
Dawid Give it to me [takes matches from L2]
Judy Ok, take it
Mara Open the gas tap…slowly. Come on, open.
Judy Do you know what you supposed to do?
Dawid yah
Mara come on [the gas made a puff sound. Then she closes the gas tap immediately].
Judy You see [laughing]
Dawid [opens the gas tap slowly and put on the light while controlling the tap] Because you can't do it on your own.
Judy It must actually be blue light.
Mara Control it here.
Judy Ooouugh [finally the flame became blue] waaagh. Yes now what will we do next? [holds the leaf in her hand]
Dawid We must boil it.
Judy Put it in here.
Mara Let me read. We must draw it first.

Themes emerging from Episode 1

Firstly, Episode 1 appears to show that students interacted with one another following a certain pattern of communication which was typically I-R-E-R-E-R-E- authoritative chain. I stands for initiation, E stands for evaluation and R stands for response given. Judy, however, seems not to dominate the discussion. In this episode, Judy responded to others eight times while others, Judy and Dawid responded five times during the discussion. Secondly, in this episode, students' responses to one another were verbally or physically communicated. For example, Dawid asked Judy if he/she, Judy was scared while Dawid asked Judy in another incident to give her the matches (action carried out). Thirdly, the students focused their discussion on two issues, namely: handling of materials and the performance of the skill needed in this instance to use or operate a Bunsen burner (including controlling the gas tap). Thus, much of the students' talks centred on the use and handling of materials and scientific equipment. The only observation that one can make from the episode is where he students made reference to the 'blue' light of the Bunsen burner. Fourthly, the distribution of duties was not discussed explicitly but the students appeared to know their responsibilities within the group. None of the students needed to be reminded about certain duties that they neglected. Every student took upon her/himself to carry out a duty towards the completion of the task.

Episode 2

Episode 2 was taken from the students' interactions in the middle of a lesson in Christie's practical class. The students' verbal interactions focused on the application of the process skills. Christie was the teacher and here is a segment of their conversation:

Kerstin	Just put it on the tile. You open it up when it is on the tile.
Erika	[Put the leaf on the tile eventually and started unfolding it out nicely. The leaf has lost most of its green colour now.]
Ben	Where is the iodine [pass iodine bottle to Erika.
Erika	[Took the second leaf out of water bath]
Ben	[Pour iodine… seven drops on the leaf already spread out on the tile, covering the whole leaf with iodine solution].
Kerstin	You cannot see the difference between the original and …
Ben	But we won't see anyway [pour more iodine solution till the whole leaf was covered nicely with the iodine solution].
Theres	Leave it for a while
Christie	What are you going to do now with excess iodine solution?
Carol	Yah ask him that, mum.
Erika	[In the meantime took out the second leaf, spread it nicely on the tile next to the first leaf
Christie	What will you do with the excess iodine [on the leaf]?
Ben	Pour water

Johan Now do it

Ben No wait first [laugh]

Christie It won't have an effect on your results when you get it off?

Ben No mum

Christie Yes

Theres Will it?

Ben No

Kerstin It won't change it [the leaf]

Christie Why not?

Kerstin We are actually washing it off

Christie What colour will it change to?

Carol Inside?

Christie What is inside?

Kerstin, and Carol: Cell.

Ben Inside the cells

Christie So if you rinse the surface it will not have an effect?

class No [chorus]

Christie Washing out iodine on the surface will not have an impact, ne?

Themes emerging from episode 2

The pattern of interactions seems to be affected by the number of students in a specific group. The nature of the interactions was completely diffused and seemed not to follow any specific pattern. Sometimes, a response (R) was followed by an action (A) or vice versa action (A) following a response (R). For example, responses in the first three lines (Kerstin, Erika and Ben) followed by lines six to eight (Kerstin, Ben and Theres) in episode 1. The responses from different students seemed to be dominated by a few students such as Ben and Kerstin with 8 and 5 counts respectively. For example, John did not responded in one way or another in this episode. The focus of the exploratory discussion was on the following aspects:

- Handling materials and apparatus in terms of performing the process skills, for example, 'Just put it on the tile. You open it up when it is on the tile.'
- Questioning one another about issues that they were unsure about, for example, 'where is the iodine?', 'will it (change colour)?', 'it won't change it?'
- Providing explanations in terms of proving evidence about what was done or observed, for example, 'you cannot see the difference between the original and…'
- Making suggestions about what should be done to complete the task at hand, for example, 'Leave it for a while', 'but we won't see anyway.'

The manner in which the students provide suggestions, explanations and questioning others seemed to signal to others what next step needed to be taken. In episode 3, the students' communication strategy was networked in such a way that they could assist one another.

Episode 3 General food test: apple sample

Episode 3 was taken from the middle of a lesson, a little bit towards the end of the activity. The group in Jarijo's class had only three students. Their conversations were as follows:

Willem	We need to have a pulp.
Chris	Yah [*grinded pieces into pulp*] Get water from the tap.
Willem	It won't be necessary [*grinding pieces further into pulp*].
Benny	what?
Chris	Get water from the tap, yes.
Willem	Watch this colour change. Is still yellow or what is the colour change?
Chris	No change [*still grinding the apple pieces into pulp*]
Willem	No change? Are you serious? No change? [*TT1 no colour change. Yellow is the same colour as iodine*]. It must change to black-blue in this one.
Benny	In this one?[*pointing to TT1*]
Chris	This one is negative.
Willem	No in starch test.
Benny	What colour is starch test?

Willem It must go black-blue
Benny So we are getting colour change or must go clear?
Chris not really
Willem [*Put apple pulp into all four test tubes*]
Chris Let us first put the stuff [*apple pulp*] in all of them.
Benny Ok [*added water to all test tubes by trying to pour equal amount of water into all test tubes. They also have cleaned the first test tube*]
Willem [*mixed the content of all test tubes by shaking each very well*]
So far everything went on smoothly and the hot water bath is also ready.
Willem Now you add the reagents. This is alcohol.
Benny [*took TT2, added alcohol and Benedict's solution droplets to it*]
Willem [*TT2 added iodine solution droplets to it – put into hot water*] What is that?
Benny Benedict's test [*colour changed from blue to green*]
Chris No. what have you done?
Willem [*went around reading. They mixed up the reagents in TT2*] Mum, where is Fehling A?
T This is Fehling A and Fehling B. add 5 drops of each.
Chris Let us read first. [*paged through the manual*]
Benny Now, we will do the emulsification.
Chris Work with alcohol. Bring the alcohol. [*reading from the manual]*. Look at TT2 is changing colour. Is this starch test? Which one is this one? [*TT2 is in hot water*]
Benny is milky
Chris you mean there is fat in it?
Benny Is milky [*difficult to make a ruling between cloudy and apple suspension*]
Chris is just the same
Benny Yah is just the same
Chris This is alcohol [*pointing to TT1*]
Benny emulsification, yah
Chris What colour is this? [*pointing to TT2*]
Benny Orange
Willem Glucose test?
Chris Yah, is glucose test [paging through the manual] and this one? [*pointing to TT3*]
Benny Is like blue
Chris Is not blue
Benny Is blue, is Benedict's solution
Chris Is not blue
Benny Green blue.
Chris There is no such a thing in here [*paging through the manual*]
Benny Yah. What colour is that?
Willem Purple?
Benny Yah this is negative.

Themes emerging from episode 3

The pattern of the verbal interactions in Episode 3 reveals the typical I-R-E-R-E-chain where I - represents initiation, R – represents responses and E - represents evaluation of the response. Episode 3 was characterized by three different exploratory moments. One, the students focused their exploratory discussion on (i) procedures, (ii) observing and recording results, and (iii) the interpretations of experimental results. For example, the following statement: "we need to have a pulp" signalled that they should grind the apple pieces into a pulp, that is, they needed to deploy a certain process skill, namely manipulative skill. It was also observable from the episode that the students spoke about the experimental results and the last part of the discussion centred on the interpretations of results. Lastly, they were also able to notice that there was an error in the way they followed the procedures due to the negative results they obtained compared to what was in the manual. Thus, the focus of their exploratory discussion was on the following aspects:

- Practical procedures in terms of performing process skills.
- Results that were observed in terms of scrutinizing the positive colour change.
- Realizing the importance of reading procedures as well as being aware of what colour change they should look for.
- Realizing that they needed to repeat the practical activity due to negligence of not adhering to what they needed to do.

Table 4.16 summarizes the student-student interactions within the classroom discourse in a group experiment. Because the three episodes were taken from different lesson moments, it becomes difficult to make comparisons. Because the students' actions seemed to change across the lesson moments, that is, the students tended to perform different tasks during the same practical activity. For example, during the first moments of the lesson, the students' discussion focused on the manipulation of materials and apparatus as well as the performance of process skills. Lastly, the discussion shifted from carrying out procedures to making observations and interpreting observable results. Such a demarcation of activities was observed during the student-student interactions in group experiments seem to be beneficiary to students in negotiating scientific discourse (Beeth, 1998).

Table 4.16 shows that the pattern of interactions across the three episodes remained basically the same, that is, I-R-E-R-E-R-E-chain although the focus of the discussion had changed as the lesson moment changed. The group with many members appeared to deviate from the normal pattern of interactions. It was also observed that some members of a group dominated the discussions while others were completely inactive. Such a pattern of communication might have serious effects on the learning styles because it seemed to create minimum opportunities for the students to engage in distributed interactions where all the students were actively involved in activities. Furthermore, there was a need for Jarijo to structure students' work and responsibilities as well as guiding and facilitating the roles of the students within the groups (e.g. Beeth, 1998; McNeil & Krajcik, 2008).

Table 4.16 Student-student interaction in an experimental group

		Episode 1 **Jarijo**	**Episode 2** **Christie**	**Episode 3** **Jarijo**
Patterns of interactions	verbal and non-verbal (actions)	I-R-E-R-E-R-E-chain; one student dominated the discussion	I-R-E-A-R-A-R-E-R-chain, that is, diffused chain; some students dominated the discussion	I-R-E-R-E-chain; equal participation in discussion
Focus of discussion	Procedural	√	√	√
	Resources	√	√	√
	observation			√
	Interpretation of results			√
Types of exploration	questioning ideas	√	√	√
	explaining ideas		√	
	criticising ideas	√		√
	offering an idea/answer	√	√	√
	reinforcing responses		√	√

As explained earlier, the episodes were neither taken from the same lesson nor taken from the same classroom environment nor supervised by the same teacher although these episodes seem to represent events within the lesson moments in a similar manner. For example, every lesson had an introduction, main moment of presentation and the concluding moment. These episodes represented the events taking place in group experiments in a similar manner. Episode 1 is a typical example of what took place during the first part of group experiment and episode 2 represents what took place during the first part of the second moment of group experiment, while episode 3 is cutting across the last section of the second lesson moment as well as the concluding section.

Table 4.16 also shows that the focus of discussion in episode 1 and episode 2 remained the same. The students sampled their discussion on procedures and the use of materials and apparatus. However, the focus of discussion in episode 3 changed from procedures to resources and then lastly centred on the observations and interpretations of the results. The students appeared to use different strategies in exploring ideas and establishing meanings during the learning process. The following themes emerged from analysing the episodes: questioning, explaining, offering ideas as well as criticizing and reinforcing each other's ideas. Questioning and offering new ideas or answers seem to be a common occurrence and appeared across the three episodes while the act of explaining took place in episode 2.

In analysing the learning instances within the three episodes above, it is apparent that the patterns of interactions, the organisation of duties, the participation and negotiations of meanings differed from group to group as well as from one practical activity to another. Learning in student-centred classes is a process of active engagement in the construction of knowledge (Walczyk & Ramsey, 2003) and the development of practical skills and the use of scientific tools. Learning does not take place in a vacuum but meaning-making is negotiated socially and culturally as well as through the medium of language (Hodson & Hodson, 1998a; Nakhleh et al., 2002; Richardson, 1997; Roth, 1995; Staver, 1998; Zady et al., 2002). An examination of the three learning episodes in group experiment reveals to what extent the students were able to discuss and negotiate meanings at the class level. In other words, it shows to what extent the participating students were able to gain knowledge when they participated in student-student discussions when the teachers were not directly involved. For instance, when the students worked on common group experimental tasks, they tended to learn and developed new knowledge (Mortimer & Scott, 2003). Mortimer and Scott (2003) argued further that:

> The process of learning and developing that is being described here is not one that involves ideas being transferred directly from teacher to student, parent to child or friend to friend. What is involved, for each participant, is an ongoing process of comparing and checking their own understandings with the ideas that are being rehearsed in the social plane (p. 10).

However, the point of interest here is how the students assisted and guided one another as they attempted to make meanings about what they were learning in terms of: the language of science (exploratory talk); the skills that they needed to perform; the procedures that they needed to follow; the materials that they needed to use as well as the distribution of responsibilities to members of the group (Bennett, 2003; Jones, 2000; Roth, 1995). In other words, the focus of interest here, as Roth (1995) puts it, is on "learning which is viewed as an apprenticeship in the practices of a culture."

4.3.2 School B

The situation at a school B, however, differed in terms of equipment availability and the sitting arrangements in the laboratory. The laboratory had long benches arranged alongside each other. There were no water or gas taps fixed in the laboratory and students sat on normal chairs. The students used paraffin stoves to warm water for their experiments. The only water tap that was in use was at the teacher's working station in front of the class.

In addition, there was a small store room next to the laboratory where the teacher kept the chemicals and the few laboratory equipment. The laboratory structure at school B is common to most of the schools where the majority of black children are schooling. As per information interview the teacher at school B, Lena, indicated that she did not have enough equipment and that hindered her teaching very much. She preferred to carry out teacher-demonstrations as practical activities after theoretical lectures due to the lack of equipment.

4.3.2.1 Demonstration lessons observed

In this section I focus on some of the common practical activities in Biology laboratories that were conducted through teacher demonstrations at School B. In doing that I explore the opportunities that the biology teacher, Lena, provided in order to mentor and mediate learning through dialogue.

One of the aims of practical work in science lessons is believed to be the demonstration of scientific facts and theories to students. Some teachers in science classes were observed while carrying out demonstrations in order to provide opportunities for their students to acquire procedural and conceptual skills by observing scientific phenomena. It was observed that in some cases the teachers' teaching styles also determined the strategy to be used in instruction. This is, for example, in line with Harlen's (1999) view that teachers tend to be affected by the availability of the type of equipment in making choices deciding between demonstration and laboratory bench work. In the case of Lena, she had chosen to carry out demonstrations than involving her students in small group laboratory work due to a lack of equipment as she had indicated in the interviews that I had with her. Thus, what seems to be important here was whether or not the approaches she used were helpful into her attaining the purpose of the teaching she did. In this case Lena carried out teacher demonstrations and was assisted by two or four students for each activity. The activities were conducted in front of the classroom at the working station of the teacher. She read through the practical procedures from the handouts and students carried out the instructions as she instructed them.

There were 37 students in the class. All of them attended the teacher demonstration lessons and were requested to complete their practical tasks and hand their practical exercise books to the teacher before the next practical period, (i.e., a week before the next practical session). Only 33 exercise books were handed in. Six of the 33 students did not complete their exercise book for vitamin C test. These exercise books were photo copied and were used as additional documents that were analysed in order to enrich the data. There were seven demonstration lessons that I observed that focused on different food testing and included the following practical activities:

- A test for starch
- Benedict's test for reducing sugars
- Biuret test for proteins
- Testing food for fats (the emulsion test) and
- A test for Vitamin C

The students were presented with two demonstrations, (i.e. the test for starch and the test for fats and oils on the first day, then the test for protein, reducing sugars and lastly with the test for vitamin C). The demonstrations aimed at developing practical skills as indicated in section 4.2 Figure 4.1. The following Table 4.17 shows the extent to which Lena was mentoring and sharing ideas with her students in order to develop the intended practical skills:

Table 4.17 Teacher's activities performed during teacher demonstration lessons

Teacher's Activities Category		Descriptors of activities	Counts	Total
1	Practical skills	37. Manipulates materials/ apparatus	13	34
		38. Makes measurements		
		39. Reads instructions	9	
		40. Follows instructions	12	
2	Carry out demonstration	41. Uses real specimen/materials	2	9
		42. Prepares solutions just before starting with demonstration		
		43. Carries out the activity	7	
3	Provides assistance to students	44. To carry out an activity	16	17
		45. To take measurements	1	
		46. To carry out an activity in a small group		
4	Describes what to be observed	47. Event, phenomena		60
		48. Patterns		
		49. Remarks about what should be observed	21	
		50. Content, apparatus and materials used	39	
5	Explanation provided	51. About an event, phenomena	2	6
		52. About the procedures to be followed in completing a task	4	
		53. About a procedure in taking measurements		
6	Opportunity provided to	54. Make and record observations	20	40
		55. Complete a table	20	
		56. Make and record measurements/estimates		
		57. Discuss results/ anomalous results		
7	Shares ideas	58. Science content or procedural information	8	28
		59. Repeat an idea	15	
		60. Share group/student's findings	1	
		61. Asks students to prepare or complete a table, a graph		
		62. Reminds students about safety precautions, format to write report	4	
8	Selecting ideas	63. Work on ideas		0
		64. Developing the scientific story		
9	Shaping ideas	65. working on ideas		0
		66. developing a story		
10	Marking key ideas	67. working on ideas	2	2
		68. developing a story		
11	Checking student understanding	69. probing for meanings	1	4
		70. probing a specific group for meanings		
		71. checking on continuity	3	
12	Reviewing	72. returning to and going over ideas		0
Total				**200**

Table 4.17 shows the flow of the discourse in the classroom. Most of the time, Lena's focus of intervention was on sharing ideas (category 7) with the whole class while she focused less attention on other categories such as selecting and shaping ideas as well as reviewing ideas. She also seemed to focus less on marking key ideas as well as checking on the students' understanding. Table 4.18 also shows the form of teacher utterances where the focus was placed on category 4 about the descriptions of what were to be observed, followed by the opportunities provided for the students to make and record their observational results and complete the given table worksheets. However, the table indicates that there was little focus placed on providing appropriate explanations (category 5) about phenomena and procedures to be followed in completing tasks. Table 4.18 also indicates the extent to which Lena performed her roles and skills in the flow

of discourse. Lena focused on performing practical skills such as manipulating apparatus and materials following procedures. Lena hardly performed any practical demonstration. Overall, category 5 (providing explanation) enjoyed little attention from Lena as well as other categories of teacher interventions that seemed to involve discussions and assistance at higher level than providing assistance in following procedures and using apparatus and materials.

In the following sections, some specific episodes are presented to demonstrate the extent to which Lena mediated learning through dialogue at the social or inter-mental plane of the classroom under the following themes: teacher actions in the flow of discourse (practical skills), form of teacher utterances (descriptions of what should be observed) and teacher intervention (sharing ideas).

a) Practical skills that Lena performed

A few examples of the practical skills are offered in episodes 1 to illustrate the types of skills as performed by Lena during the demonstrations.

Episode 1.

Lena: So now we are not going to use teat-pipettes but we have syringes because we don't want you to dye your hands. What is going to happen? Put on gloves on hands. These are the beakers. [S*he calls upon few students to join her in front.]* Each one of them [*students*] will pour their substances into the beakers. They will pour equal quantity of each substance every time.

Lena: Come on this side. I will pour 2ml of the dye in each beaker. They will pour 2 ml of food solution every time. They are going to do it more or less four or five times.

As it can be observed from this episode, most of the practical skills performed by Lena were focused on lower cognitive level such as manipulating apparatus and materials, reading procedural instructions and following procedural instructions sequentially. Other process skills such as fair testing, thinking skills, identifying variables, making rational decisions about which instrument to use, discussing observable results, constructing graphs and tables were lacking from the demonstrations lessons.

This may be related to the fact that the process skills that Lena performed or assisted her students to develop are at low procedural skills level. The high level conceptual skills and the focus of such skills were on the teacher rather than on the students where the teaching approach needed to be student-centred than teacher-centred (Boz & Uzuntiryaki, 2006; Martinez-Lusada & Garcia-Barros, 2005; Oh, 2005; Trumbull et al., 2006). There seems to be a restricted effect on the role of the teacher in the co-construction of meanings and scaffolding skills in supporting the development process skills at higher level through teacher demonstrations as it lacked features of supportive dialogue (Chin, 2006; Morge, 2005; Ramorogo, 1998; Wu & Hsieh, 2006). Observing colour change without dialogue might not be enough in making meanings. Thus, teacher demonstrations performed in this manner seem to have a variety of shortcomings such as that the teacher will tend to focus on those skills that s/he feels confident of managing and performing (Frost, 2005; Ogborn et al., 1996); lack of appropriate planning (Frost, 2005); preferred teaching style or behaviour (Harlen, 1999) and engagement of students in dialogue (Frost, 2005) might be problematic while carrying out a demonstration.

b) Describing what is to be observed

In practical work, observation is regularly conducted by teachers and students. Although observation is an important aspect of practical work, it is problematic because it is accompanied by theories. Wellington (2000) asserts that no student can observe events or phenomena without a framework. He further argues that observation is hardly pure and is complex. It is theory-driven and therefore, students need to be told what to look for in observing colour changes. The next episodes illustrate this aspect of providing information to students.

Episode 2.

Lena: This is a starch test. The reagent is iodine solution. So I am going to use a blocking tile [*put the blocking tile with 12 small holes on the table*]. Put one spatula from each food sample at the holes at the corners on the blocking tile. What is this called? [*the teacher is holding a blowing pipette in her hand*].

L pipette [*choir*]

Lena: Yes is called a blowing pipette because you are blowing through it. Iodine solution has a brown colour and if a substance we are looking at contains starch, we are expecting a blue to black colour.

Episode 3:

Lena: So we are looking out for a bluish colour. You can see that this is the iodine solution colour [*pointing to the bottle with iodine solution*].

L We are looking for a black or blue colour, ne?

Lena: You make your choice.

L Is this the potato, mum? [*pointing to the tile. There were no labels next to the food samples in order to identify the food samples*].

Lena: Yes. This is the potato, peanut. Maybe I should add more peanut just a little bit. [*then, she added peanut to another hole on the tile and three drops of iodine solution on the food sample*].

In both episodes, Lena provided information to the students that they would need to make appropriate choices about what they would observe and the type of objects observed during the demonstrations. In addition, descriptions of what were to be observed go well beyond the language (Ogborn et al., 1996) and what was being observed (colour change). For example, to make meaning, Lena used iodine solution colour as a blueprint to be used by students in deciding whether the colour had changed or not. Thus, observation without being linked to theory would be meaningless.

Secondly, in the first episode Lena did not involve her students in dialogue as compared to the second episode. In the second episode, Lena provided room for the students to communicate with her. However, instead of Lena being more accommodating and probing or involving the students in an argumentation (Abd-

El-Khalick, 2005; Erduran, 2006; Ogunniyi, 2006), she responded to the students in a non-arguable way. Therefore, there was a need for Lena to provide opportunities for mediating, scaffolding and making meanings at social or inter-mental plane in the classroom.

c) Nature of teacher intervention (sharing ideas with students)

The laboratory/classroom is a dynamic complex environment. There are many factors that affect the teaching and learning process such as the personality of the teachers and students, the social context of the classroom, the availability of resources, teaching and learning styles, teaching practices, forms and focus of interactions and all in all, the classroom atmosphere as well as the complexity of the dialogue between the teacher and students (Chin, 2006; Haney & McArthur, 2002; Liang & Gabel, 2005; Morge, 2005; Welzel et al., 1999). The verbal utterances of the teacher need to act as a mediator by providing guidance or a framework in assisting the students to make sense of what they are learning. The students need multiple forms of teacher intervention and multiple learning opportunities to learn (Puntambekar & Kolodner, 2005; Shepardson & Britch, 2006). The following episodes provide some important information concerning the nature of teacher intervention that Lena provided to her students in order to support their meaning-making.

Episode 4.

Lena: We now must also do the DCPIP test. This <u>refers to di-chlorophenol-indophenol. This also called the blue dye</u>.

Episode 5.

Lena: Ok, we <u>said if it changes colour than it has vitamins C</u>. Now, they did all twice [measuring 4 ml of each solution]. The orange was only done once.

Lena: <u>If we had here something else than orange that only take 1 ml of DCPIP, because orange took 2 ml to change, then it would has more vitamin C than the orange.</u>

As observed from laboratory/ classroom as well as from the given episodes above, Lena focused on category 7 (sharing ideas) and 11(checking students' understanding while category 8 (selecting ideas), category 9 (shaping ideas), category10 (making key ideas) and category 12 (reviewing ideas) were not fully utilized. It appears that Lena focused less on utilizing teacher intervention strategies in order to provide guidance in making meanings at social or inter-mental plane during demonstration lessons. The lack of dialogue might have contributed to the poor teacher intervention strategies. In fact the lack of dialogue might be related to a lack of practising student-centred approaches to teaching and learning than teacher-centred approaches in demonstration lessons (Walczyk & Ramsey, 2003).

Table 4.18 Students' Activities Performed during Teacher Demonstration Lessons

Students' Activities Category		**Descriptors of activities**	**Activities performed**
1	Practical skills to:	a) Follow sequence of instructions	few students
		b) Handle materials/apparatus	few students
		c) Collect materials/apparatus	no provision made
		d) Make observations	all students
		e) Make measurements	few students
		f) Read procedures	all students
		g) Complete worksheet	all students
2	Carrying out demonstration tasks	h) Carrying out a task individually	
		i) Carrying out a task as assisted by teacher	few students
3	Recording data or observations	j) Individually	all students
		k) In small groups	no provision made
4	Interpreting and make conclusions	l) Individually	all students
		m) In small groups	no provision made
5	Discussing ideas	n) With peers	some students in small groups
		o) With teacher	no provision made
6	Reporting experimental findings	p) Individually in writing	all students
		q) In small groups in writing	no provision made
		r) orally	no provision made

Table 4.18 indicates that only few the students who assisted Lena could perform some of the process skills such as following instructions, handling materials/apparatus, making measurements and carrying out some practical tasks as assisted by Lena. Teacher demonstrations have also their shortcomings and strengths. What was observed was that Lena read instructions step-by-step to the student who assisted her. Then, the students were rather involved in listening more to Lena than in handling the apparatus/materials than following the instructions by themselves.

In analysing the practical examination, all process skills except carrying out demonstration could be assessed in practical examinations. However, only few students were able to develop the intended practical and experimental skills as prescribed in the MEC, NSSC Biology syllabus (2006). Nevertheless, the students were provided with the opportunities to develop some intended skills by completing worksheets.

The next section deals with the analysis of the students' practical books in order to establish the extent to which the students could record the observational results.

4.3.2.2 Analysis of students' practical books

In this subsection I analysed and interpreted the students' exercise books in order to establish the extent to which the students could record the observational results. Thirty-three practical books from the students were analysed. The Table 4.19 below illustrates the students' performance on the given categories.

Table 4.19: Observational Results Obtained from Food Tests. (N=33)

Category	Reagents	Onion	Potato	Peanuts	Orange
R1 (Starch test)	27	29	30	29	30
R2 (Fats & Oils Test)	24	30	9	30	30
R3 (Protein Test)	8	30	31	31	21
R4 (Reducing Sugars)	19	23	17	16	23
R5 (Vitamin C Test)	18	25	25	12	25

The Table 4.19 shows that the majority of the students performed well on recording the colour changes for the test for starch as compared to how they recorded the results for the test for fats and oils. It is, however, surprising that most of the students provided partially-correct answers for the test for fats. Overall, the difference is not statistically significant except in the case of the potato where the difference is significant. When a student, **Cecilie** was interviewed about what was difficult in identifying the colours, the student had this to say:

R: What difficulties did you experience in identifying the colours?

Cecilie: Sometimes is difficult because when you sit you see different colour when you are close to it. It seems that it changes again. You don't really know that it will change again. Some people came [in front] for the second time just to make sure and some don't understand what is going on.

R: What did you do to be sure of the colour changes?

Cecilie: Yah just write down according to what you think because sometimes you might think that the answer is wrong but in fact is the correct one. You just answer according to what you think is correct.

R: Did you talk about it with the teacher or with other students?

Cecilie: Yah, we ask each other.

The above excerpt demonstrates how observations that appear to be straightforward can sometimes be flawed to the students. This problem could be worse when students are colour-blind. When students observe freely, in other words, observe with little direction from the teacher, they tend to report wide-ranging and conflicting observational results (Brooks et al., 1989). However, further analysis of the students' recorded results indicate that they had more problems than expected with the observation and recording results of some food tests such as the test for reducing sugars, the test for proteins and the test for vitamin C. The Table 4.20 illustrates some of these problems.

Table 4.20: Observational Results Obtained from the Fat and Oil Test. (N=33)

Categories	Correct	Incorrect	No answers given
R1 (Test for starch)	29	1	0
R2 (Test for reducing sugars)	14	16	0
R3 (Test for proteins)	10	20	0
R4 (Test for fats)	21	9	0
R5 (Test for Vitamin C)	13	11	6

The results obtained from the fat and oil test were really confusing. The results for both the potatoes and protein solutions showed a positive result, that is, when ethanol was added to the solution, it produced a milky appearance or what Lena referred to as 'cloudy white' colour. It came as a surprise for me because I expected her to explain what she expected the results to be and what really happened. She simply looked at the potato emulsion solution twice and then told the students that there was only one positive answer to the test. Such an observation opened up the doors for guessing or simple theoretical memorization of what the positive result of such a test is supposed to be.

This was a possible opportunity where Lena could have opened a discussion forum for anomalous results or maybe repeated the test several times before concluding that there was only one positive result for the fats and oils test. When I looked into students' exercise books I found out the she marked the students' work wrongly when they recorded positive results for both the potato and peanut solutions. The only possible explanation that I could think of was that she contaminated the solutions in the beakers or that the potato was handled with fatty hands. Talking about anomalous results could have been a good way to explain to the students why the result was wrong instead of keeping quite. When student, **Anna** was asked what difficulties she found in completing the worksheet, she had this to say:

R: What was difficult in completing the worksheet?

Anna: It was easy because we needed to see the colour change and write the results [positive or negative]. There we saw it for ourselves when she demonstrated to us. But for the other answers are either she say that by herself or you read in the book.

R: What was difficult then?

Anna: With some (referring to colour changes), yes, it was quite difficult because she tells us, for example, it should turn a yellow-green colour but when you go there the colour looks dark-green and that kind of a thing is confusing. But at least we debate about it with the others.

R: Did you ask the teacher for help?

Anna: No but she told us that there should be one positive answer, for example, and then the others should be negative. So we know that this should definitely be positive and the others should be negative.

The next day Lena continued with the tests for proteins and the reducing sugars as if nothing happened. The results were recorded and presented as follows:

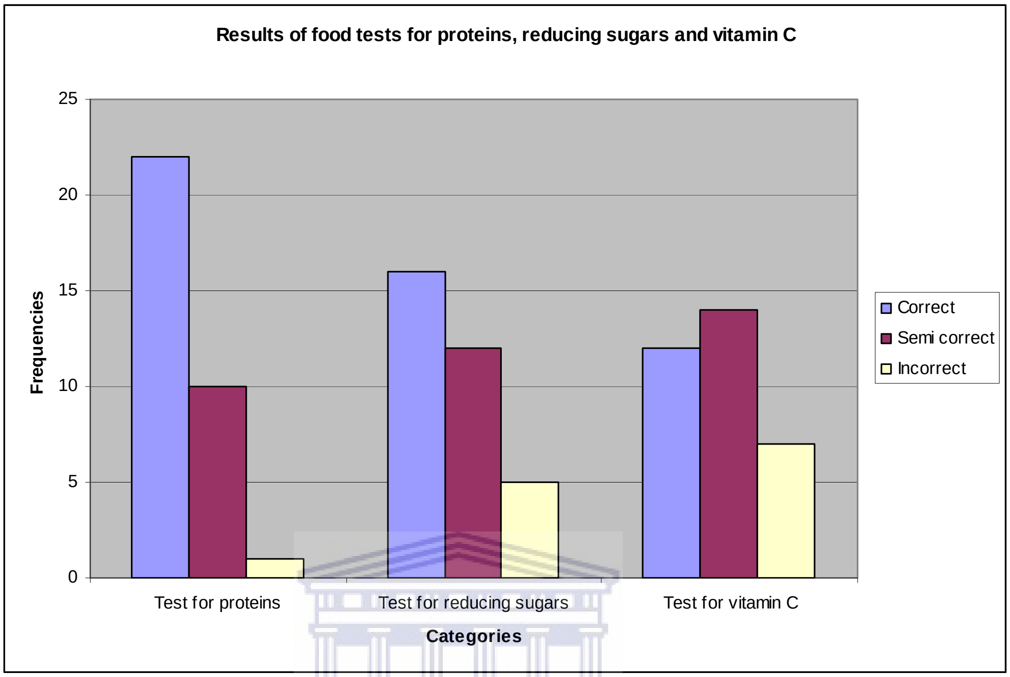


Figure 4.3: Observational Results Obtained from Reducing Sugars, Proteins and Vitamin C Tests. (N=33)

Figure 4.3 shows that a large number of the students (66.7%) recorded the results for protein test correctly, while 30.3% of them who handed in their homework also indicated that proteins were present in other food samples than only in peanuts and only 3.03% of the students recorded incorrect answers. This trend is also recorded in the results for the reducing sugars. Forty-eight point five percent of the students recorded correct answers for the test for the reducing sugars. However, the number of students who recorded partially correct answers increased to 36.4%. The result for the test for vitamin C was, however, surprising. The number of students who provided semi-correct (42.4%) and incorrect (21.2%) answers increased considerably when compared to the first two food tests.

The concern here is with the semi-correct answers. One would want to know why students provided wrong answers. It was clear from the demonstration that only orange juice contains vitamin C and none of the other food samples. When some of the students were asked if they experienced any difficulties with the test for proteins they responded as follows:

R: What was easy or difficult when completing the worksheet for the test from proteins?

Zandré: Most like the blue, the purple colour because one of them turned clear and the other one stayed people almost a medium like purple-blue. So because you fill in the boxes which one has that food substance, so it was kind of hard because it was in between, almost light-blue and purple?

R: How did you arrive at the correct colour?

Zandré: I just looked at it and as the other colours turned lighter I think the food substance was basic but in the other colour is just a little bit clear. You could see that there was only a little or small quantity of that food substance because it didn't change the whole thing.

When a student was interviewed if she experienced any difficulties with the test for vitamin C a student, **Harrian**, responded as follows:

Harrian: Yah there was one. I think it was for the vitamin test. The colour wasn't very clear.

R: What did you do to get the correct answer?

Harrian: I just think is blue like that but it was lighter in colour.

In addition to recording the positive and negative results from their observations, students were also expected to write the reagent that was used in testing the food sample for the presence of the particular substance. Table 4.13 shows observational results recorded by the students to indicate the reagents that were used in food testing for all food tests.

Table 4.21: Observational Results Obtained from Reagents used in Food Tests. (n = 33)

Categories	**Correct**	**Semi correct**	**Incorrect**	**Blank**
Test for starch	30 (90.9%)			3 (9.1%)
Test for fats and oils	27 (81.8%)			5 (15.2%)
Test for proteins	9 (27.3%)	18 (54.5%)	1 (3.0%)	5 (15.2%)
Test for reducing sugars	24 (72.7%)		3 (9.1%)	6 (18.2%)
Test for vitamin C	22 (66.7%)			10 (30.3%)

Table 4.21 shows a systematic decrease in the way students recorded correct results across the food tests. The majority of the students (91%) recorded the correct reagent for starch. This is followed in a descending order by the test for fats and oils (82%); testing for reducing sugar (73%) and testing for vitamin C (67%). However, only 27% of the students managed to record the correct reagent for the protein test. The students seemed to face a variety of challenges with the test for proteins. This is the only category where the students gave a high number of partially correct answers. It is also interesting that the number of students who did not complete the worksheet increased from starch test, 9.1%, to vitamin C test, 30.3%.

During teacher demonstrations, much of the noise that often included reading instructions, manipulating equipment and making measurements (Harlen, 1999) was removed. The students' tasks were minimized to fewer practical skills such as recording results and negotiating with group members in arriving at an appropriate conclusion. In other words, teacher demonstrations seem to create opportunity for the students to spend time on curriculum-related activities with the purpose of learning. This is in line with Harlen's (1999) argument that practical work should be both task-oriented and curriculum related. He proposed that in order to develop scientific understanding it is better to rely on demonstrations, expositions and discussions. In his view, discussions as well as activities where students repeat tests seem to clarify confusing results than other instructional strategies.

Discussions seem to be important and should go hand in hand with the demonstrations to equip students better in what they are learning.

From the foregoing, it seems reasonable to suggest that the end product of demonstrations alone without an appropriate discussion about the inherent strengths and weaknesses of such an approach might not provide enough room for the students to be enculturated in the norms and values of scientific practice. For example, a study conducted by Brooks et al. (1989) revealed that students may restrict their observations to what they know or want to see happening. However, without a teacher-led discussion around the topic being demonstrated, the students may fail to perceive the necessary links and connections between theory and practice. Because such a discussion will provide opportunities for students to talk about anomalous results as well as design other strategies to improve the observed results. Demonstrations followed by discussions or concurrently run along side each other may provide the opportunity for students to learn more about the nature of science and scientific practice.

One of the central roles of the teacher within a constructivist classroom is to lead the students to new levels of cognitive understanding (Vygotsky, 1978) during a given classroom/laboratory discourse. However, teacher demonstrations carried out by Lena were more of monologues of reading of the practical procedures rather than a true dialogue between her and her students. Mental sharing of scientific ideas seemed to be absent when the teachers involved the students in practical demonstrations. For instance, colour changes might not necessarily lead the students to scientific ideas unless the teacher used such pieces of evidence as a platform for students to concretize their understanding of the phenomenon in question. In a number of demonstrations that I observed, the students' attention was drawn to the positive colour changes brought about by the reagents used to test a given food substance. In a particular case, when a teacher added iodine solution to a certain white food substance some specimens turned dark-brown while others turned blue-black. Now, which colour change should a student report, the dark brown or the blue-black? Certainly a class discussion would have been appreciated here but the teacher thought creating such an opportunity would have given away the answer to her students. One would have thought that the opposite should have been the case because there is a wide difference between engaging students in a discussion and telling them the solution to a problem. The excerpt below, derived from an interview with some students, illustrates this point further:

> **Anna**: It was easy because we needed to see the colour change and write the results [positive or negative]. There we saw it for ourselves when she (Lena) demonstrated to us. But for the other answers are either she says that by herself or you read in the book.
>
> R: Was it difficult to identify the colours?
>
> **Anna**: With some, yes, it was quite difficult because she [Lena] tells us, for example, it should turn a yellow-green colour but when you go there the colour looks dark-green and that kind of confusing. But at least we debate about it with the others.
>
> R: Did you ask her [Lena] for assistance?
>
> **Anna**: No but she [Lena] told us that there should be one positive, for example, and then the others should be negative. So we know that this should definitely be positive and the others should be negative.

The above excerpt is indicative of the need for dialogue between the teacher and her students to clarify misunderstandings that might have arisen in the minds of the students as a result of the demonstration in question. Arguing and debating with other students or with the teacher is necessary as such a dialogue tends to help students to appropriate scientific knowledge (Nakhleh et al., 2002; Staver, 1998) in an attempt to internalize the new information at a personal level (Roth, 1995). The teachers should not take it for granted that the colour changes are obvious but should involve students in dialogues in order to enhance their understanding of the phenomenon in question. The teacher should assist students in unlocking the meaning embedded within what is being observed (Lijnse, 1995). Telling students that a given response is correct or is incorrect only promotes rote learning as it does not allow the students to externalize their misconceptions or doubts (Ogunniyi, 2007b).

Another shortcoming that emerged from Lena's demonstration is her students' complaints that they were not given enough opportunities to practise how to follow her instructions and to manipulate apparatus/materials. When some students were asked about this they expressed the following sentiments:

R: What do you prefer, is it to do the practical activity yourself or teacher demonstration?

Eluyno: No I want to do it myself

R: Why?

Eluyno: Because so that we can feel if we can make a mistake then she [Lena] can help us and you can do something about it.

R: What about if Lena does it?

Eluyno: Then you don't feel involved in this.

Another student said:

Roxanne: preferably doing it myself

R: Why?

Roxanne: Preferably myself. If we do the things ourselves and write examinations then we recall things better instead when we do alternative to practical work.

Another student said:

Zandré: I would prefer to do it myself because I may know what happened when, what to throw in where, the quantity and all the stuff.

R: Is it difficult if some is demonstrating for you?

Zandré: Is not difficult but I think it would be better for us to do it for ourselves and so we can be more explained to what is happening in the reaction. So we can know in the exam if we get the paper we forget everything and just see a question you remember we did that and that.

From the foregoing interview with the students, some important themes that emerged were: 'doing it myself'; 'learning from one's mistake and making necessary correction'; 'feeling being neglected or uninvolved'; 'being better prepared for the practical examination'; 'gaining procedural skills'; 'responding to questions based on practical experience rather than memorized facts'; and 'knowing what quantity to add'. Students indicated that they had a variety of concerns about teacher demonstrations. All these are important issues that highlighted some of the weaknesses in teacher demonstrations that teachers and examination officers need to consider in teaching and assessing students on practical work. Studies (McCarthy, 2005; Puntambekar & Kolodner, 2005; Shepardson & Britch, 2006) have shown that students need multiple forms of support and multiple opportunities to learn. Such opportunities should provide students with a dynamic and complex environment that will introduce them to multiple forms of activities rather than simple teacher demonstrations lacking individual, multiple and collective zones of interactions during the teaching and learning environment.

The previous comments from the students indicate deep problems for the initiation of students into the learning science, learning about science and doing science and point to a need for well planned thought-out teacher demonstrations or practical activities in a student-centred classroom. What seems to emerge from the students' comments above is a sense of connection or a bridge from their experiences as active participants to what they know and needed to know about practical work. Such a sense will only provide different ways of learning (Maoto & Wallace, 2006; Walczyk & Ramsey, 2003). The next section deals with teachers' views and beliefs about practical work as well as the extent to which such views and beliefs informed instruction practices of the teachers in Biology laboratory and classrooms.

4.4 What are the Biology teachers' views and beliefs about laboratory work and how do such views and beliefs inform their instructional practices in the Biology laboratory/ classroom?

The focus of this section has been to analyse and interpret the data pertaining to the biology teachers' views about laboratory work in terms of their instructional practices. This entails classifying such views and beliefs in terms of how the teachers implemented practical work at the two school sites and the dilemmas they faced in preparing their students for the practical examination.

4.4.1 Teachers' views and beliefs of practical work

In Namibia, the practical examination is taken in three different ways (i.e. (i) 'Practical Examination', (ii) 'Applied Practical Skills' and (iii) 'Coursework' examinations). At the two school sites students were enrolled for the 'Practical Examination' and 'Applied Practical Skills'. The students enrolled for Higher Level normally take the Practical Examination while the students enrolled for the Ordinary Level take the "Applied Practical Skills' which is a theoretical paper. In addition, the students enrolled for the NSSC Higher Level and those enrolled for NSSC Ordinary Level are taught in the same class under the same conditions in Namibian schools. Some schools do teach their students in separate classes but these are the rare cases. The students enrolled for the Higher Level and Ordinary Level at both school sites were mixed groups. Although they faced different practical examinations with distinctly different requirements, they were nevertheless taught in the same way in the same class. Mixed ability teaching for practical work is a big challenge for teachers and need to be taken seriously by both the teacher trainers and curriculum designers. It requires careful thought and planning as well as a sensitive approach if students' varied needs and abilities are to be catered for.

The next subsections present data on the teachers' views and beliefs about practical work and how these inform their instructional practices.

4.4.1.1 Christie's views and beliefs about practical work

The students in Christie's class were enrolled for both 'Practical Examination' and the 'Applied Practical Skills' examination and also taught in the same class. As Christie indicated this is not an easy thing to do. Although she liked to organize practical work to prepare her students for the 'Practical Examination', she found this task onerous in such a large class. To Christie:

> Practical Test is like this exam [practical examination] that we are doing now. Coursework is done through the two years and you take their marks throughout these two years but that takes up a lot of time. Because just imagine there are 80 students and you have to mark, I think is about six practical, in the course of the year. How much time goes in that work? How will I ever get through with my teaching? Otherwise, I will have to do this in the afternoon, get the kids to school to do the practical in the afternoon. And then you can only have one at a time at a working station, like now [*referring to the way students have to sit for the examination: setup in class. Students are working individually and there should be no discussion amongst them.*]

The excerpt above suggests that though Christie would like to teach practical work she nevertheless faced the dilemma of an overwhelmingly large mixed ability class. She argued that students enrolled for the Ordinary level were less motivated and put little effort to their work. In addition, she pointed out the need for the Ordinary level cohort to do practical activities in the same way as those enrolled for Higher Level cohort although it is not compulsory that she should do so. Christie's argument for teaching the Ordinary level cohort in the same way as the Higher Level cohort goes as follows:

> Because I teach them as one class and I feel that it is unfair keeping them in the classroom and letting the other do the work in the laboratory. So, I let the whole group in [the laboratory] and they enjoy it. I think they get a better idea of the 'Alternative to Practical' examination then when they have done it themselves in class.

Teaching practical work in such a large class as Christie's is a common feature in Namibian schools and indeed many African schools (Onwu, 1998). But Christie's decision to teach the Higher and the Ordinary Levels together is based more on a moral argument and their dualistic beliefs (Bryan, 2003) than the scarcity of human and material resources which might well be equally valid reasons for her choice of instructional strategy. But appealing as the phenomenon of large classes the concerned research findings in the area are still inconclusive. This matter is discussed further later on.

As indicated earlier, Christie's did not like students working in groups but circumstances beyond her control forced her to use group work as a teaching and learning strategy in practical work. Equally, Christie felt that it was fair for students enrolled for the 'Alternative to Practical' (Ordinary level) to do the same practical activities meant for the Higher level. Although students seemed to enjoy these activities, her argument was that students tend to acquire more practical skills when involved in doing the practical activities themselves rather than discussing activities theoretically. When I asked her what influenced her in deciding to use this mixed mode approach practical she gave the following reason:

> In the beginning, I got it [information] from the INSTANT Project group and I also mark at the end of the year examination papers. So, we [biology teachers] get together there and we talk. We ask each other and discuss nice textbooks that are new on the market and things like that. I learn a lot because it [marking external examination] shows you how the people mark. What kind of answers they want? What kind of specific language they want? How exact the students have to be, for example, how do they mark a graph? You know, if you have never seen that how will you ever know?

Christie's view was that her marking experience influenced her decision to mix both the Higher and Ordinary Level students. Her discussions with team leaders and other expert teachers helped her to become aware of the standard expected both in the teaching of practical work as well as alternative to practical work. Another disturbing issue that Christie mentioned was that teachers seemed not to receive much assistance from the examination officers and subject advisors. For example, she said that she did not even know who the subject advisor for Biology was. This peculiar situation might not be unrelated to the shortage of humanpower- a common feature in many African countries (e.g. see Ogunniyi, 1995; 1996).

4.4.1.2 Jarijo's views and beliefs of practical work

The students in Jarijo's class were enrolled for the Ordinary Level, that is, students would only take the 'Alternative to Practical' examination and not the 'Practical Test' unlike the case of Christie and Lena who taught mixed ability groups. Thus, Jarijo unlike her counterparts was not exposed to teaching students who enrolled for both Higher and Ordinary levels. As indicated earlier in section 4.2.1.1. (b) in this chapter, Jarijo prepared her students in a similar way to Christie. She commented on this idea as follows:

> Grade 8 and 9, first we teach them all the equipment. For example, I take all the equipment out and put them out for them and I show them … this is a Bunsen burner and you do this and this with it. So they have an idea and they know exactly. This is what you do with it and I explain safety precautions and things because you are in the lab. Precisely we do these things in grade eight and nine and I do simple experiments. You can do that with them as well and showing them how to use a Bunsen burner, how to treat a leaf and all of these things. So by doing simple experiments I prepare them for grade 11s and 12s. With the new curriculum it is compulsory for the grade nines.

Jarijo's views of introducing students to practical work provide room for her to involve students in a variety of activities. Preparing students for practical work involves more than what is described in the syllabus. In the excerpt above Jarijo explained how she induced her students in doing practical work. Such an induction involved students in handling apparatus and materials as well as being aware of safety precautions. As a result of this induction, students were given opportunities to be familiar with laboratory equipment and simple experiments. Such an induction seems to provide more opportunities to students to gain knowledge of laboratory equipment and safety precautions before being involved in complex practical activities. Unlike teachers in a study conducted by Koosimile (2005), Jarijo seemed to provide a foundation for students to acquire general information about familiarising them with the conditions of the biology laboratory.

Jarijo pointed out that she liked to teach students who were enrolled for the 'Alternative to Practical'. The reasoning behind her idea was that the grade 11 students were very difficult to control and work with. She echoed her view about the students as follows: "I like the grade eights and nines because they are easy to work with and you can explain to them. They understand and they want to learn. But the grade 11, they are not interested. They are very difficult to work with." Jarijo's teaching concern seemed to pave a way for her to control the students. Jarijo seemed to have no problem with younger students because she could control them. But she seemed to have problems with students in higher grades who seemed to resist her strictness and control over what they wanted to do, particularly, when they had to carry out practical activities in groups where the noise level was normally higher than the lecturing sessions. In other words, Jarijo wanted to be in control during her teaching periods.

Although Jarijo did not teach students who enrolled for the Higher level, she took her students to the laboratory regularly and she also did the same practical activities as Christie did. This seems to indicate that Jarijo exposed her students to practical activities which required the performance of practical tasks not required in the alternative to practical work. Jarijo's students carried out practical activities in the same manner as those students who would write 'Practical Test' examination. But Jarijo did not teach mixed ability groups at all. In addition, she considered the students to be lazy, for example, she said: "They are very lazy, some of them, I am not going to say all of them, some of them are very lazy. They want us to spoon-feed them."

According to Jarijo, students tended to have a better understanding of practical work when they were involved in doing these activities rather than having theoretical discussions about practical activities. In addition, Jarijo expected her students to have certain understandings that would enable them to complete the practical examination successfully. She expected them to develop the following process skills:

> They should be able to understand the stuff that is number one. Is no use of letting them do something and then they have no idea what is going on. I have to explain to them for example, we are doing this and the reason is this. So that they know at the end if you wanted to see this I will do that and why do that. When I am going to the lab I, always tell them that we are doing this and I want this at the end. They must be able to see this and that. So to me they have to understand first and then they have to be able to do the practicals themselves. They should be able to read it, make observations, if they have to convert things. Sometimes they have to give an answer in cm and are asked to measure it, then they do it in mm, then they add it, the cm and mm and they don't get the correct answer. So they have to be able to do these things, measuring, observing and doing it themselves and so forth.

The excerpt above, illustrates Jarijo's instructional strategies and in turn, these strategies could be understood in terms of how she perceived practical work. It seems to be important to her for the students to have a good understanding before going into the laboratory to perform practical activities. For instance, she spent time to explain to students what they should do and what the outcomes of the activity would be before she took them to the laboratory. Jarijo's belief is that of equipping students with sufficient understanding before getting involved in practical activities on their own.

Jarijo reiterated her instructional belief and practice as follows:

> I will explain at the beginning and they have to do it themselves because when the exam time comes I won't be there to explain to them and to do it for them. They should be able to read it and do it themselves. That's the main focus especially when I am dealing with students at higher grades.

Jarijo's instructional philosophy could be described as active learning and practical activities backed by an understanding of what was to be done. When students were in the laboratory, Jarijo did not interrupt them unnecessarily. She indicated that she preferred that they spend some time reading before they start off with the activities. She believed that students will not unnecessarily repeat practical activities that were carried out by following an incorrect procedure. She commented by saying:

> They have to be very, very careful. That's why they need to read before they do anything so that they know exactly. So the problems I experienced is that they don't read. They just come in there and go on. It is so much easier if they read the night before or take the first five or ten minutes [in the lab]and read, know exactly, for example, look I have a Bunsen burner, a glass beaker and I must use this test tube, and that and that. Then they can go on. But now they do it first and then they read then they do it over. That takes up time and they may not finish.

This is one of her concern in teaching practical work. In wanting to provide opportunities for the students to be actively involved in practical activities, Jarijo indicated that she changed her roles in order to fit the situation. She emphasized the point that she walked around during the laboratory session in order to see what the students were doing. Her view was one of avoiding disrupting students unnecessarily. She indicated that, "Usually I accompany all the practicals with a question worksheet so that they can fill it in and tell me what they understand or what they got from the practicals."

In addition, Jarijo like Christie preferred students working in mall groups rather than in large groups. She suggested that individual work was lonely and could be intimidating to students. To her, "If they are working individually in the beginning, it can be intimidating. Imagine standing there and you don't know what to do and you don't have friend around you."

Jarijo indicated further that she was not involved in marking external examination papers like Christie but that she relied very much on her Head of Department who gave her a lot of assistance. The excerpt below is representative of her sentiments:

> I have a subject head who helps me a lot and always go to her and ask her what is wrong with this or what I can't do and whatever. So we have these printed books that are already prepared [practical manuals]. And with any question about the curriculum, I go to her and then she explains it to me. I can go to her

> with anything and she will always listen and try to come up with a solution. She is very helpful.

The next subsection deals with the views and beliefs of Lena teaching at School B.

4.4.1.3 Lena's views and beliefs of practical work

The first part deals with Lena's views and beliefs about her instructional practices relative to practical work. Like her counterparts in School A, Lena also conducted practical work, though for a shorter a shorter period of time. Her students are introduced to laboratory work as early as grade eight. She indicated further that the programme only runs from the beginning of every year. The following excerpt is reflective of her instructional practice:

> At the beginning of the year, I show them how different types of practical are done. I give short demonstrations and on how to do the write-up of it; how to answer the questions and to do the write-up of everything so that you can come up to a conclusion of that. Most practicals are based on how to analyse results, how to use data and interpret them. I do that at the beginning of the year. These are just short demonstrations in order to equip them when they start with real practicals in grades 11 and 12. So, that they at least know what is expected of them.

Lena's goal was to use these short demonstrations to prepare her students for the more challenging laboratory activities and practical examinations in grades 11 and 12 respectively. However, my observations showed that Lena did not provide enough opportunities for her students to acquire even the lower process skills such as following procedures, using and handling apparatus and materials, making estimates and measurements except for observing and recording results of observations. Lena as the main demonstrator carried out most of the process skills that were meant to be practised and carried out by the students.

The students in Lena's class were exposed to both the 'Practical Examination' as well as and the 'Applied Practical Skills' examinations. They were also taught in the same classes. She indicated further that she preferred to teach students who were enrolled for the 'Alternative to Practical':

> I prefer the 'Alternative to Practical' examinations. Actually it fits nicely in with practical examination itself. Like I told you I do all these experiments with the children and then afterwards give them some worksheets. So, once that practical is set, they have seen the results and the questions they ask every one, they know what result is.

As indicated in section 4.2 Lena preferred to carry out teacher demonstrations and gave the students very limited opportunities to carry out laboratory activities individually. Lena suggested that her students would gain knowledge when familiarised with process skills and she further considered it to be essential for her to give them theoretical lessons which were in alignment with what examiners were likely to ask in the practical examinations. For example she said that:

> If you have your lesson on osmosis then you do that practical on osmosis and afterwards you give a few questions on osmosis. Even taking out from old question papers, for example, the 'Alternative to Practical' and you give them those worksheets then it works out nicely. You see then one thing lead into another.

Lena's instructional practice seemed to be underlined by the belief that when she aligned her teaching with what was examined in the external examination, the students were likely to perform well in such examinations. She seemed to rely heavily on what was likely to be examined rather than helping the students to develop critical process skills enunciated in the biology curriculum. In order words, passing examination was the driving force in her instructional practice. As can be remembered, Lena only exposed her students to teacher demonstrations and very rarely allowed them to carry out the practical activities on their own. The question that arises is, "Can teacher demonstrations alone be enough to prepare students to answer complex practical activities such as designing and carrying investigations or demonstrating procedural skills simply by playing the role of a spectator? “This is more so when it is realized that the processes involved might occur at a very fast rate as to allow one sufficient time ask relevant questions.

Lena also pointed out that she taught both Higher and Ordinary level students in the same classroom and in the same way although they were writing different examinations at the end of grade 12. She commented further that the students writing the ‘Alternative to Practical’ examination needed to do the practical work individually too and work with equipment individually. She contended that the students needed to experience observe her demonstrations because later on they would work in a laboratory at the Universities. She highlighted the importance of the students being involved in practical activities individually by saying:

> I prepare them in the same way, the Higher and the Ordinary level children. And those methods actually just for Higher level children but are beneficial to the Ordinary level children. It is not necessarily that I can only do practical demonstrations where I show them the results and give them worksheets on that. But that I could do with the Ordinary level children but is much beneficial if they see (my emphasis) that for themselves and they experience it themselves.

The above excerpt reveals Lena’s assumption that seeing or observing a phenomenon in a demonstration necessarily implies grasping or experiencing such a phenomenon. This of course may not necessarily be the case. Watching an experiment performed by an expert is not necessarily the same as performing it by oneself. As several of Christie’s students pointed out, there is a great difference between a spectator’s and the hands-on experience of an expert namely, the teacher. Like Jarijo, Lena surely wanted to help her Ordinary Level cohort by exposing them to the same instructional context as those in the Higher Level category rather than plan activities at different levels of difficulties. As stated earlier, she believed that presenting teacher demonstrations to the Ordinary Level students was adequate to prepare them for the Alternative to Practical Examination. Unlike Christie her concern was not on ethical grounds but the expediency brought about by the shortage of material resources:

> You see, that our equipment and chemical are not enough. I want each and every student I wish I could get it like that, that each and every student could do it individually and have their own equipment and work all on their own. That's what I am trying to do but is not possible at the moment.

It seems that the inherent structure of the Educational System is prohibiting her to provide opportunities to students to carry out practical activities individually. Further, Lena seemed to be struggling against her tendency to teach in the traditional way while at the same time she seemed to be aware of the benefits that could result from involving her students in hands-on practical activities. She attempted to pacify her inner conflict by heaping the blame on the lack of laboratory resources.

Lena, like Christie, went through an in-service training programme when they were introduced to the Cambridge Education System by INSTANT programme in Namibia during 2001. However, when the newly revised biology curriculum was implemented, the three teachers namely, Christie, Jarijo and Lena did not receive any in-service training for practical work. Hence, the teachers relied very much on their previous teaching training knowledge. Lena indicated that she worked in a group with other biology teachers in the nearby schools and in most cases they only exchanged worksheets. According to Lena:

> The lady at Upurua Secondary School and the gentlemen at Jaama High School sometimes we give few worksheets and stuff to each other about practicals that we do not understand and that how we assist each other. Insecurity and lack of knowledge may force teachers to use certain practices that they could avoid when they receive assistance and guidance from their superiors.

Lena and Jarijo enjoyed teaching students enrolled in the 'Alternative to Practical', while Christie enjoyed teaching students enrolled in the 'Practical Test'. The students at School A where Christie and Jarijo taught carry out practical activities by themselves in small groups while the students at School B were exposed to practical work through teacher demonstrations. However, the teaching strategies used for laboratory work seemed to be similar in both schools. As indicated earlier, teacher demonstrations compared to group work provided fewer opportunities for the students to acquire most of the process skills as well as at higher levels of cognitive understanding. When the students performed the practical activities themselves they seemed to gain most of the process skills that otherwise could not have been acquired through simple observations.

From the analysis of the laboratory manuals and the worksheets used by Christine and Lena there seemed to be no differentiation made in the practical tasks given to the students enrolled for Higher- or Ordinary level. Instead, students at both school sites where taught in the same manner. Although Christie and Lena considered their all-purpose, one coat-fits-all instructional practices to be beneficial to their mixed ability students, it was difficult to ascertain this. Ideally, the students should have been taught in different groups because the requirements for the two practical examinations differ.

Further exploration has indicated the complexity of teachers' views and beliefs (Boz & Uzuntiryaki, 2006; Gwimbi, 2003). The teachers' views and beliefs from the study suggest that the teachers had entrenched and manifested beliefs described in the Keys' (2007) in the 'Knowledge Filter Model'. Table 4.22 shows how the three Biology teachers' views and beliefs reflect that model.

Table 4.22: Triangulation of the teachers' views and beliefs

Teachers	Expressed Beliefs	Entrenched Beliefs	Manifested Beliefs
Christie		Coursework is done through the two years and you take their marks throughout these two years but that takes up a lot of time	In the school we have a policy and we start as early as in the grade 8s. Here, when they are coming. We get them accustomed to the lab. You just take them in there once and show everything.
		Because just imagine there are 80 students and you have to mark, I think is about six practical, in the course of the year. How much time goes in that work? How will I ever get through with my teaching?	Practical Test is like this exam [practical examination] that we are doing now.
			Because I teach them as in one class and I feel that it is unfair keeping them in the classroom and letting the other do the work in the laboratory. So, I let the whole group in [the laboratory] and they enjoy it.
			So, we [biology teachers] get together there and we talk. We ask each other and discuss nice textbooks that are new on the market and things like that. I learnt a lot because it [marking external examination] shows you how the people mark.
Jarijo			Grade 8 and 9, first we teach them all the equipment. For example, I take all the equipment out and put them out for them and I show them.
	.		Precisely we do these things in grade eight and nine and I do simple experiments.
			So by doing simple experiments I prepare them for grade 11s and 12s. With the new curriculum it is compulsory for the grade nines.
			I have to explain to them for example, we are doing this and the reason is this. When I am going to the lab I, always tell them that we are doing this and I want this at the end.
			So they have to be able to do these things, measuring, observing and doing it themselves and so forth.
Lena	At the beginning of the year, I show them how different types of practical are being done. I give short demonstrations	I prepare them in the same way, the Higher and the Ordinary level children. And those methods actually just for Higher level children but are beneficial to the Ordinary level children.	Even taking out from old question papers, for example, the 'Alternative to Practical' and you give them those worksheets then it works out nicely.
	These are just short demonstrations in order to equip them when they start with real practicals in grade 11 and 12. So, that they at least know what is expected of them.	I want each and every student I wish I could get it like that, that each and every student could do it individually and have their own equipment and work all on their own.	I prepare them in the same way, the Higher and the Ordinary level children. And those methods actually just for Higher level children but are beneficial to the Ordinary level children.
			But that I could do with the Ordinary level children but is much beneficial if they see that for themselves and they experience it themselves.

As examination of Table 4.22 reveals a sort of mismatch between Lena's views and instructional practice on the one hand and the goal of the 'Alternative to Practical Work' on the other. Much as she claimed that the Ordinary Level group equally benefited from her demonstrations like their counterparts in the Higher Level group, she did not seem to present sufficient evidence for her stance. Hence, her view about the purpose of teacher demonstrations and possible benefits of this approach in terms of hands-on experience by students seem to be based on speculation rather than on reality (Brown & Melear, 2006; Keys, 2007).

Christie and Lena showed how their entrenched views and beliefs (expressed verbally or non-verbally) actually informed their instructional practices. Christie and Lena were of the view that both the Higher and Lower Level students should benefit from their instruction. However, they did not seem to be able figure out how to do this without benefiting one group at the expense of the other. For example, Christie elaborated on why her school enrolled students for the 'Practical Test and not for 'Coursework'. She indicated that 'Coursework' demands a lot from the teachers to mark their students' work. Apart from being time consuming in terms of marking a large number of scripts, it puts an extra burden on teachers who are already overloaded with work. For quite another reason, Lena taught her students through demonstrations. She however, did not provide a viable argument to support her believe that vicarious or spectator experiences gained from such demonstrations were as authentic as students' hands-on experiences gained through personal involvement in practical work.

Much as Christie and Lena adduced reasons for their unique and 'one-fits all' instructional approaches, they did not state explicitly how using the same form of instruction for distinctly different groups of students facing different types of examinations, would automatically benefit from such a practice. Like other teachers, Christie and Lena perhaps had not taken sufficiently time to clarify the contradiction extant between their beliefs and practices on the one hand and the curriculum goals on the other. Nor have they construed their enthusiasm, believe and practices as based on faulty assumptions about learning (Brown & Melear, 2006; Crawford, 2007; Gwimbi, 2003; Keys, 2007; Verjovsky & Waldegg, 2005).

All the three teachers indicated that their views and beliefs coincided with their philosophy of teaching (Bryan, 2003) namely, to expose students to instructional protocols that would benefit them despite the curriculum goals. Based on my observations and the information derived from the students' interviews, however, the three teachers seemed to implement one aspect of practical work or the other (Keys, 2007). In other words, the teachers seemed to establish clear routines and to conform to certain acceptable and expected notions on how to teach practical work. Teachers may work hard to implement what they belief in or what seems to be attainable and other not (Bryan, 2003; Crawford, 2007; Martinez-Losada & Garcia-Barros, 2005; Trumbull et al., 2006). Such views allowed them to get through the syllabus and prepare their students for the practical examinations.

The teachers' views and beliefs mentioned above are personal and context specific (Verjovsky & Waldegg, 2005) and should rather not be generalised to all teaching and learning environment. Teachers' views and beliefs about the teaching and learning process are factors that could influence their instructional practices (e.g. the way they teach, plan lessons or assess students) as well as their professional development (Lotter et al., 2007; McNeil & Krajcik, 2008; Verjovsky & Waldegg, 2005). The next subsection deals with the students' views about their teachers' instructional practices in relation to the teaching of practical work in the school sites where the study was conducted.

4.4.2 Students' views about their teachers' instructional practices during practical work

Thirty-six students were interviewed about the ways their biology teachers taught practical work. However, due to lack of space only a few excerpts are cited to illustrate the students' perceptions of the way their teachers organized or presented practical work. Four issues worthy of consideration in this regard are: (1) the students' perceptions of practical work in general; (2) the students' perceptions of group work in practical work; (3) the students' perceptions of teacher demonstrations, and (4) the students' concerns about the teaching of practical work in their respective schools.

4.4.2.1 What are your views or general feelings about the teaching of practical work, particularly working in small groups, in your school?

It is important to note as indicated earlier that in School A where Christie and Jarijo taught, the students were given ample opportunities to work in small groups during practical sessions. Although Christie and Jarijo had different perceptions of collaborative learning, they nevertheless organized group activities which they believed would enhance their students' practical skills. The students of these two teachers expressed diverse views about their teachers' instructional practices. Some of the students' comments focused on instructional strategies while others were on individual practical activities that they performed during the day. For example, Werner felt as the excerpt below shows that Jarijo did an excellent work.

> **Werner**: That they should keep on doing it at every school. Actually to make it (practical work) a compulsory thing because it is quite interesting and children will enjoy it.

Another student said:

> **Sam**: Practical work is very, very good. My teacher [Jarijo] she likes really practical work. She does proper work. She works through our things. She will tell us what we do is wrong and then you can learn like that and I like practicals.
>
> R: Why do you think that they are good?
>
> **Sam**: I think is good that we do such tests [activities] because we are going over the work again but in a more practical way. Then we tend to think about things differently as well, think a little bit more logically, ask more questions and learn a lot more.

Another student said:

> **Ben**: The teacher is an excellent teacher. Some teachers, they just give us the work and she [referring to Jarijo] explains and go through with you and if you have questions she will answer it and she is really interested and committed to what she does.

It is clear from the comments made by **Werner** and **Ben** that the students were involved in carrying out practical work at School A. It also seemed that they were happy with the way Jarijo at School A was teaching them practical work. **Werner** and **Ben** indicated that Jarijo seemed to provide clear explanations and feedback about practical activities. However, not all the students provided positive comments about the teaching of practical work at School A. For example, **Peter** was disappointed about the incorrect results he received from an activity and he seemed to be frustrated by the timing that was never enough to complete or repeat some of the activities when he needed to do so. **Peter** commented:

> I was in a way kind of disappointed in the results mainly we were testing for test sugars, starch, proteins and both the things we tested they were both proofs and mainly there just starch or glucose of the results. I was kind of disappointed because I wanted to see the other. The time was not enough.

Group work or cooperative learning was practised during laboratory sessions in School A but not in School B. the students worked in small groups as mentioned earlier consisting of four to eight students in specific groups. The biggest group in Christie's laboratory consisted of eight students with five girls and three boys. From this group, four of the girls were Black, one White, two Black boys and one Coloured Boy. **Willy** was in this group and he described his views about the teaching of practical in the next excerpt:

> **Willy** My general feeling is that if you are working in this group, just that everybody wants to do it the way they want to do it. Maybe they want to do everything because there's a camera and there's microphones and whatever and everybody just wants to do the way they want to do it. Then I actually can't concentrate and all the other people in the group. So not all of us or maybe we are one or two in a group, including myself didn't get a chance to actually do something in the group. So maybe tomorrow I will do an experiment by myself tomorrow so that I can see what I am doing and understand what I am doing because today I didn't understand anything because everybody is just jumping ahead and doing the things by themselves. The one girl, she was doing everything by herself. You know before I even knew it, the experiment was over. So I couldn't actually see what she was doing.
>
> R You didn't participate?
>
> **Willy** I didn't participate a lot although I really did one, two things and that kind of things make me frustrated.

Working in small groups was not that rosy. Willy seemed to experience different problems not only related to understanding the work (concepts/ events under discussion) but also trying to work together in order to make sense of what they were doing. Willy experienced problems in working with others but girls dominated the discussions instead of boys as generally found. However, Christie was not aware of the problem. The discussion seemed to indicate that there was little or no distribution of responsibilities to the students which created room for some students to dominate the activities on the disadvantage of others. The role of the teacher is an essential factor in structuring students' work, responsibilities, guiding and facilitating the roles of the students within the groups. In addition the teacher needs to support students in making sense about what they are learning (McNeil & Krajcik, 2008). Thus, it was important for Christie to take control about the responsibilities of proper functioning of the group in the completion of the given work.

Secondly, Willy made another comment about working individually. This is a very important issue and needs to be considered seriously. During an interview with Christie she indicated that although she did not like students working in groups, she was forced by circumstances. The materials and chemicals were expensive and she needed to save somehow. But while Christie's reason for organizing group work instead of individual activity might be justified, it still does not rule out individual students in a group playing specific role. That was the contention of Willy namely that he did not have enough opportunities to participate as frequently as he would have liked because one girl played a domineering role.

Also, as much as possible students should have opportunities to work on an individual basis. This view is vividly expressed by Joseph who said:

> It is better to do the practicals yourself than someone tell you in class how the experiment should be done. I think you remember better if you do it yourself.

The students' comments about their views and feeling towards practical work are summarized below:

a) Positive comments

- Teachers must provide opportunities to students to carry out practical at every school. It is good and should be made compulsory.

- Practical work gives students a second chance to go over their work in a practical way, that is, a chance to think about the work in a different way and in a logical manner.
- Some of the students sampled thought that their teachers were committed and they went an extra mile with them in order to explain and assist them.
- Some students preferred to carry out practical activities themselves and argued that they could remember what they observed in a better way or experienced personally than being spectators of other students.

b) Negative comments

- Sometimes the students became disappointed when they got negative results and in addition, the time was not enough to repeat their activities.
- Sometimes group work also frustrated the students when some of them dominated all the activities and discussions.

The next subsection focuses on the students' views and feelings about teacher demonstrations at School B where data were collected.

4.4.2.2 What are your views/ feelings about the demonstration you have just observed?

As already pointed in section 4.2, Lena exposed her students to practical work mainly through teacher demonstration. When the students were asked to state which practical activities they enjoyed most, demonstration was one of the activities that were ranked the lowest (see section 4.3). In order to find out the students' views about Lena's instructional practice, twelve randomly selected students were asked on different occasions how they found the demonstrations they had just observed. Their responses were then analyzed to identify the similarities or differences in their perceptions of Lena's instructional practices relative to practical work. Due to lack of space only four students' responses are considered in this report. The students interviewed held a variety perceptions about Lena's demonstrations. For example, Cecilie said:

> I think it [demonstration] is good because it helps during the examination when at least like you see how the stuff was being made. So it make much easier for you because you can see the picture in your mind and you can get the answers much faster. Because you see, then, you answer the questions according to what you see.

Clearly, **Cecilie** felt that demonstrations are good and listed some of the advantages that she attached to observing objects or events. To her, it gave her opportunities to observe (see) and remember things for her examination which is better than nothing. Another student, **Eluyno's** views about demonstration are presented in the excerpt below.

> R: What are your views/ feelings about the demonstration?
> **Eluyno**: I want to do it myself not demonstrations
> R; Why?
> **Eluyno**: Because so that we can feel if we can make a mistake then she can help us and you can do something about it.
> R: What about if the teacher is doing it?
> **Eluyno**: Then you don't feel involved in this.

The excerpt shows that **Eluyno** did not like demonstrations and preferred to carry the practical activities himself. He wanted to become actively involved but not simply observe how the teacher was carrying out the demonstration. Another student, **Roxanne** said: "I feel better when I am doing it myself then I know next time how to do it, what I should add and so on, preferably myself." Another student, **Zandré** commented in the next excerpt as follows:

> **Zandré**: I would prefer to do it myself because I may know what happened when, what to throw in where, the quantity and all the stuff.
> R: Is it difficult if some is demonstrating for you?

Zandré: Is not difficult but I think it would be better for us to do it for ourselves and so we can be more explained to what is happening in the reaction. So we can know in the exam if we get the paper we forget everything and just see a question you remember we did that and that.

The above presentation is a clear illustration of the students' views and feelings about teacher demonstrations. From classroom observations, it was also clear that most of Lena's practical activities were presented as teacher demonstrations as discussed in section 4.2.1.3. In addition, it was also observed that Lena's demonstration did not provide the students with the opportunities to acquire most of the intended process skills as indicated in Table 4.18 and Table 4.19.The student' comments about their views and feelings towards teacher demonstrations are summarized below.

a) Positive comments

- Some students considered teacher demonstrations to be good because they gave them an opportunity to make and record observation data. They argued that they were better than not carrying out practical activities at all.
- However, a considerable number of the students felt that they wanted to carry out practical activities themselves and not only rely on teacher demonstrations. They also wanted to be sure that they could carry out the procedures by themselves and not make mistakes.
- The students were convinced that they would be able to explain things in detail if they did the activities themselves.

c) Negative comments

- The students felt that they were left out if the teacher carried out the demonstrations.

The next subsection deals with the students' choices of the best way they can learn when taught practical work. Two alternatives were provided as textbook instructional strategy and the teacher demonstration strategy.

4.4.2.3 Which way do you think you will learn better? Is it through demonstration or textbook lecture about practical work?

The above question was posed to Lena's students in School B but not to the students at School A because practical work was mainly conducted in terms of demonstrations. The students had diverse views and feelings about demonstrations. As can be seen from the views of the two students below:

> **Beverly**: Practicals [*demonstration*] is interesting and is more learnful than lessons

Another student said:

> **Anna**: I would prefer the practicals [*demonstration*] because in that way I get to do the things on my own and then is like preparation for the examination. I would rather prefer the practicals [*demonstration*] because I am actually part of that. When she does only the theory she just probably writes the things on the chalkboard and then I have to go and memorize which does not actually help much. I like the practicals [*demonstration*] much more.

The common feeling here is that the students preferred the demonstration above the textbook lecture on how to carry out practical work. This method is used regularly in some of the biology classes in Namibia where teachers do not have appropriate laboratories and equipment. Generally, the teachers present a theoretical lesson about how certain practical activities are conducted. This is not to say that Lena applied textbook lecture methods in teaching practical work. According to **Anna**, textbook lecture method provides opportunities for rote learning and students memorize the results that they have not experienced or observed. Moreover, **Charles** embraced the two types of instructional practices and he said:

> When it comes to the book – you read it but when it comes to the practicals [*demonstration*] is kind of making it easier for us to understand. So reading is also good but the practicals [*demonstration*] when you see it for yourself and you know, OK, this is how it is done, this is how it really looks like because if you have to create your own picture sometimes is not what it is suppose to be.

Cecilie was one of the students who assisted the Lena to carry out the demonstrations. At first she seemed to hesitate about why she preferred demonstration rather than other means and ways of carrying out practical work. However, she seemed not to be in favour of assisting the teacher as it was robbing her of listening and understanding the work in a better way. She further stated that teacher demonstrations are better than teacher demonstration assisted by students. Cecilie felt that students involved in assisting the teacher are disadvantaged to a certain extent. The excerpt below illustrates these ideas clearly.

Cecilie: I would prefer demonstrations.

R; Why?

Cecilie: I don't know. It is like when they demonstrate you see and gain attention and the teacher can explain what is going on. Because when you are the one doing the work you don't really understand, the teacher tells you to mix this and that. So when she is talking you are mixing and you are not really listening to her. All you do is mix but when she demonstrates, she will explain and you also get to see how the work is done.

R: So you prefer demonstrations?

Cecilie: I think the demonstration for me I learn better because sometimes in the book the answers are different from when you are doing the practicals [*demonstration*]. Is not the same [*referring to the colour changes*]. In the book, they only use the potato. They don't use the onion, orange and the other food stuff. They only use the potatoes [*use of variety food samples*].

Most of the students' views and feelings were related to how they learnt but not to how the teacher taught. To most of the students, demonstrations were considered as a part of practical work and because of this that they did not make a difference in the use of the two terminologies. The students' comments about their views and feelings towards teacher demonstrations are summarized below.

a) Positive comments

- Some of the students argued that they learnt better when the teacher conducted demonstrations than lecturing and that when practical activities were explained to them in the lecture form it allowed them to memorize information that they had not observed.

b) Negative comments

- Those students who were assisting the teacher in teacher demonstrations, did not really follow the explanations because they were busy carrying out the procedures.

The next section focuses on the general concerns that the students were experiencing with the teaching of practical work in their schools.

4.4.2.4 What are your general concerns about the teaching of practical work in your school?

The concerns as provided by the students are presented according to school sites where the study was conducted. First I start with comments for School A and then present comments for School B.

School A

Some of the students at School A suggested that there was a need for more practical work sessions. In addition, there was also a common feeling amongst the students that Christie and Jarijo should provide more opportunities for them to carry out practical work individually and not as a group. Some of the students argued that in the examination they will be evaluated individually but not as a group.

> **Sara**: I will say that it is fun and we could do it often but we also do it very often. So maybe we could like do more complicated ones where you have to think not only do this and this and that [referring to instructions]. It is really a lot of steps that you have to carry out. Maybe also experiment that we have to do by ourselves not in a group because they really test an individual and not the group.

Another student said:

> **Joseph**: It is better to do the practicals yourself than someone tell you in class how the experiment should be done. I think you should remember better if you do it yourself.

Another student said:

> **Jacob**: I think is a good thing and I think we should do more practical work than theory.
>
> R: Why?
>
> **Jacob**: I don't know, maybe is my personal feeling. I really don't like reading that much.

Willy, on the other hand, made another comment that needs the attention of the Ministry of Education and curriculum developers and said:

> I think the Ministry should suggest more practical work because today, for instance, it was like in the examination, if you have the practical in your head you don't have to be scared or stressed. Because at some schools they don't do practicals and when the things come they (referring to students) don't know what to do. But if you do it over the course of the whole year, then, in the final year examination, you already know what to do. So you can also finish on time.

There is a need for teachers to align what they are teaching with the intended learning outcomes for practical examinations. Domain C in the NSSC H- and O-Level Biology syllabus provided a list of these learning outcomes (see section 4.2.2). If teachers are doing what is expected from them, then they will not expose their students to unnecessary stress when they are writing examinations. The last concern came from **Gustav** who said: "I just tell them to use easy methods to get to different answers." This a direct call to teachers not to adhere to one way of doing things as described in the laboratory 'cookbook' manual but there is a need for them to provide opportunities for differentiated teaching in their instructions.

School B

The students at School B revealed diverse concerns in relation to the teaching of practical work at their school. Their concerns ranged from simple mathematical problems to complex needs such as to have more sessions arranged for practical work. Here are some of their concerns in relation to adequate number of practical sessions rather than two periods per a seven day-cycle in the timetable.

> **Beverly**: I prefer more practicals in the future. I would like to do more practicals.

Another student said:

> **Roxanne**: I think we should do more practical work because some children understand the work better when they do practicals.

Other students felt that it could be better for them to carry out the practical activities themselves.

> **Charles**: I prefer doing it myself. It is also OK because then I know how to do it. Then she even guides me on how to do it, what test to take; what precautions to think about. So I think it is better if I do it.

Another student said:

> **Eluyno**: I can't explain. We just went in front to see when she added the stuff. I want to do it myself
>
> R: Why?
>
> **Eluyno**: Because so that we can feel if we can make a mistake then she can help us and you can do something about it.
>
> R: What about if the teacher is doing it?
>
> **Eluyno**: Then you don't feel involved in this

In the above excerpt, **Eluyno** was in conversation with the researcher and through this dialogue **Eluyno** showed a valid point about the acquisition of knowledge, in particular, the development of procedural skills. It appears that there is a need for students to be engaged in real hands-on activities in order to practise process skills. Students will not acquire these complex skills by chance but by actively participating in activities (Gott & Duggan, 1995; Roberts, 2004; Roberts & Gott, 1999; Piggott, 2002). Another student commented as follows:

> **Roxanne**: I feel better when I am doing it myself then I know next time how to do it, what I should add and so on. I like it and it is fun especially the one part where I do it myself.
>
> R: So don't you like demonstrations?
>
> **Roxanne**: No
>
> R: Why?
>
> **Roxanne**: Then it is not worth it if it is done like that. I should do it myself then I will gain more out of it.

Another student said:

Zandré: I would prefer to do it myself because I may know what happened when, what to throw in where, the quantity and all the stuff.

R: Is it difficult if someone is demonstrating for you?

Zandré: Is not difficult but I think it would be better for us to do it for ourselves and so we can be more explained to what is happening in the reaction. So we can know in the exam if we get the paper, we may forget everything and just see a question you remember we did that and that.

Another student said:

Charles: Sometimes you here in practicals but the teacher does not explain very clearly and then is you who have to do the practicals do not know what to study, what to do for the practical. It can in a way break you down because you are trying to do your best but then the teacher does not give you the full attention. Sometimes if you do go back to her then she will say like: 'I just help you to the level I could. So it is you to carry on'. Well I do understand that I have to carry on but you have to help me actually in order to carry on.

Another important concern that came out from this conversation was that of 'explaining' ideas or concepts or procedures to the students. From the classroom observations, it was clear that Lena avoided explaining broadly to the students about the observed phenomena. For example, when the observed colour turned out to be lighter or much darker than the expected colour, Lena seemed not to explain why the colour turned out that way. These seemed to frustrate the students. **Charles** highlighted the need for more explanations from the side of Lena. **Charles** also indicated that some of the teacher's responses to their questions were de-motivating them, for example, when Lena said: "I just help you to the level I could. So it is you to carry on." Demonstrations seem not to show the natural world as is but seem to impose meaning on matter. In other words, demonstrations should be carefully planned to assist students to understand the concepts being demonstrated. The apparatus and equipment are loaded with meanings. Demonstrations seemed to be sites with tension between what was supposed to be taught and what is suppose to be observed (Bennett, 2003; Ogborn et al., 1996; Watson, 2000). Another group of students gave these multiples of concerns about practical work at

School B

> **Beverly**: Actually mathematics problems with the magnification is sometimes difficult

Another student said:

> **Anna**: We are basically fine with practical work but is not always that we do practicals, for example, in the test they ask you to draw a picture of something: "draw a picture of this experiment" and then it is hard to understand what they mean because you haven't seen the practical or carry out the experiment.

Another student said:

> **Harrian**: I thought that we would do it together. We would go to her table and do it there, to see what she is doing there to see what is going on because we only saw the results. I also wanted to see how much was added what solution was used.

In the next excerpt **Zandré** is literally complaining about the instructional strategy of Lena.

> **Zandré**: We don't use equipment from the school, maybe because there is not enough equipment to fit everybody. But she does show us all of us together. She shows us how the things work like the microscope. But she told us that we can't use it because we are too many and it will take a long time for

each child to go and look in the microscope and see and record what they see.

R: Do you know how many microscopes you have at the school?

Zandré: I think four or five microscopes. I am not sure but we have some.

R: Something else?

Zandré: I would like us to work on the microscope because I think it would be a great experience to the children who do not know the stuff. Because I was in the previous school and we did that. Our Life Science teacher just gave us the follow-up on Biology for the next year. It was interesting but here we don't have much microscopes. I don't think all of us can work on that.

It seemed that Lena's views about not having enough time and equipment were in conflict with her beliefs of her instructional strategies. With four microscopes, Lena could do a lot even with the limited time available (Jenkins, 2000) for practical work. Teachers need to realize that they are depriving students of precious experiences where they would acquire important skills.

The students' views and beliefs were based on their previous learning experiences. Their views also seemed to be affirmed by what were encouraged and rewarded in the educational system in general. The students also used already established norms to judge their teachers' instructional strategies as well as the classroom activities. According to the students, such activities should conform to the rules and norms that are already established (Langley & Eylon, 2006). In view of these situations, the students might use the concept of student-centred approach to judge the given laboratory activities.

Secondly, students at this level lacked the experience and understanding their teachers' instructional strategies and, therefore, would not be in a good stand to evaluate their teachers' instructional practices appropriately. Sometimes their comments might be flawed because being familiar with the working arrangement does not necessarily mean that it is without fault (Langley & Eylon, 2006). It seems that the teachers' instructional practices were affected by many factors and students' views alone do not provide us with enough information. Nevertheless, the students provided useful information that could be used to improve their teachers' instructional practices. The students' comments about their concerns about practical work are summarized below.

School A

- They considered practical work to be fun and they wanted to carry it out very often.
- They argued that it is better if they carried it out by themselves than the teacher telling them how the experiments were conducted.
- They suggested that they should do more complicated practical activities as well as conduct activities individually rather than in a group.

School B

- The students suggested that they should be allowed to conduct more practical activities in the future.
- The students preferred to do the practical activities themselves and not involved in teacher demonstrations only because they wanted to carry out the procedures themselves.
- The students argued that not all of them were accommodated and then they could not observe all the demonstrated events. Others complained that they only saw the results.
- Sometimes the demonstrations could de-motivate them because the teacher did not explain things (procedures and post-practical discussions) well.
- The students suggested that they needed more assistance with mathematical problems in relation to magnification.
- They suggested that there should be more exercises on acquiring drawing skills.

- They also suggested that they should do more microscopic work.

Lena and Jarijo enjoyed teaching the students enrolled for the 'Alternative to Practical' while Christie enjoyed teaching the students enrolled for the 'Practical Test'. The students at School A where Christie and Jarijo taught carried out practical activities by themselves in small groups, while the students at School B were exposed to practical work through teacher demonstrations. However, the teaching strategies applied in teaching laboratory work seemed to be similar in School A as compared to School B where teacher demonstrations were regularly conducted. As stated earlier, teacher demonstrations compared to practical work conducted in small groups by the students provided fewer opportunities for them to acquire essential process skills, especially those demanding higher cognitive activities. The students who conduct practical activities by themselves seemed to gain essential procedural and conceptual skills that they would otherwise have found difficult to develop through simple observations alone.

Two of the teachers, Christie and Lena, taught mixed ability groups. From analysing the laboratory manuals and the worksheets used during practical sessions, there seemed to be no differentiation made in practical tasks given to the students enrolled for the Higher- and Ordinary levels at all. All the students in both schools were taught in the same manner. Both teachers namely, Christie and Lena, considered the situation to be beneficial for the students enrolled for the Ordinary level because they were likely to become familiar with practical activities. On the other hand, it was difficult for the teachers to plan and teach these students who had enrolled for different examinations in biology in the same class. This is one of the challenges that the Ministry of Education needs to consider to provide quality education. Ideally, the students should have been taught in separate groups because the requirements for the two practical examinations differ.

A further exploration of the teachers' views and beliefs about their instructional strategies, especially those concerned with preparing students for practical examinations, suggests that such views and beliefs are rooted in the type of training they receive (Walczyk & Ramsey, 2003) as well as the environment that sustains their instructional styles (Angula, 1993). The teachers seemed to receive inadequate assistance from the authority authorities and this in turn, tended to limit the way in which the teachers conducted practical work in their individual schools. Unlike some teachers who received some assistance from the Ministry of Education with respect to examination preparation, both Christie and Lena indicated that they received little or no assistance from the advisory officers in this regard. These two teachers seemed to have established in their minds certain routines which they thought might help them perform their tasks of preparing their students adequately for the practical examinations. In other words, they had expectations of what the Ministry of Education should do to facilitate their tasks in preparing their students for the practical examinations but which the latter failed to do. This scenario creates a sort of dilemma for the teachers.

4.4.3 Dilemmas associated with teaching practical work

4.4.2.1 Christie

Christie's crucial challenge as a biology teacher was to organise, coordinate and facilitate practical examination with little or no equipment at her school especially for those students enrolled for the Higher level and who are taking the 'Practical Examination' at the end of their grade 12. Recalling from experience, Christie indicated that it was hard to arrange examination sessions at the school. The problem was compounded by the fact that the laboratories that were too small for the students at any given session. For example, she revealed some difficulties in relation to conducting 'Practical Test' examination in terms of getting sufficient time and space without creating chaos or an atmosphere where students copy the work of those close to them. One is too familiar with the dangers associated with crowded examination rooms and the tendency among students to spy each other's work- a practice which normally results in the cancellation of examination results of the papers involved often for the entire class. Christie further mentioned the nuisance caused by students' cell phones and the difficulty encountered in keeping the students under control. For example, students need to wait for their turn for practical test and as a teacher (invigilator) at the school they have to make sure that students do not have cell phones with them. The laboratory can only take up to 18 students at a session. Christie stated further that:

> Because when the first session is finished, students can send SMS's to their friends and the message gets to where it goes. So, say for instance, I am in group one and I send my message to a guy in group three. He got at least one and half hour to look up and study whatever he needs to know about the stuff. That's also a bit of a problem.

Christie noted that with 80 students, it takes her, with two laboratories, three and half hours to finish with the examination. Again, her argument is that with more laboratories at the school more apparatus and chemicals are needed to enable each student to take the 'Practical Examination'. She indicated that she did not know how other schools, with students over a hundred, managed running the examination sessions. I captured this dilemma when she said:

> Say we need now four sessions and for practical test here we will need four test tubes per student. If we have four laboratories, ok, remember that we must have four sets of everything for each student. The students can wash them for next session but at least you should have four sets for each student. This is a lot of money and work involved here.

In conclusion, Christie made the following revelations:

- She was forced by circumstances to operate in a way that she did not like at all. For example, her laboratory instructions were done in such a way that group work was practised rather than individual work.
- Teaching mixed ability groups in the same class had also its own problems in terms of facilitating the work of the students at different levels of understanding.
- It seemed that the teachers rarely received assistance from examination officers and subject advisors. Most of the time, the teachers relied on one another to update themselves. In addition, the marking sessions seemed to provide the opportunity to learn how to mark practical activities as well as gain some knowledge and understanding about the nature of students' difficulties in taking these examinations. The question that arises in one's mind in this regard is, "How will teachers who are not involved in marking practical examinations know what would is required of them in preparing their students adequately for practical examinations?"
- Christie's concern about the lack of materials, space or time to prepare students for practical examinations is of course another dilemma. In the face of budgetary cuts for laboratory equipment and materials, Christie seemed to have adopted a pragmatic approach by organizing students into groups even in situations where individual work could have been more preferable.
- As stated earlier, and has been amply reported in the literature (e.g. (Ogunniyi, 1986, 1996) examination practices seem to maintain a stranglehold effect on the whole education system of the two schools. The effect of this anomalous situation is perhaps most noticeable (Lin, 2007) when teachers face the task of preparing their students for practical work. A common phenomenon among teachers in poor schools in Namibia has been to run to the more resourced schools to borrow laboratory equipment. Apart from the hazards involved, how do students unfamiliar with such equipment handle such equipment within such a short time of practice? One also wonders where

> school administrators suddenly obtain funds for borrowing such equipment which they usually claimed is not available for most of the year!

4.4.2.2 Jarijo

Jarijo pointed out that she was not involved in invigilating grades 11 and 12 students taking 'Practical Test' examinations because she was not teaching them. However, she claimed to be involved in invigilating the 'Alternative to Practical' which is a theoretical paper. As stated before, students who take the Alternative to Practical Work do not perform experiments; they only do what can be regarded as "theory of practical work" in the form of paper-pencil tasks. Despite this, Jarijo considered students learning how to use microscopes to be necessary. In her view, one of the problems the school faced was the inadequate number of microscopes. According to her:

> The only thing we have couple of microscopes. When it comes to grade 12 examinations and when they want to incorporate it in the examination, then we have problems because they are not enough. We don't have enough for the examination but we do have if we want to use during the year.

Because Jarijo taught both the students sitting the Practical and Alternative to Practical Tests together, one would have assumed that her concern regarding the number of microscopes should be for the former rather than the latter. This is perhaps a case where a teacher's belief might not coincide with a given curriculum goal (e.g. Osborne & Freyberg, 1985).

4.4.2.3 Lena

One of the problems that Lena experienced was the laboratory equipment and materials that they had to buy. At school B, there was only one under-resourced Biology laboratory. Apart from being too small, the laboratory had a lot of nonfunctioning gas and water taps. At the time of the data collection, Lena was teaching two biology classes with 39 and 42 students respectively in grade 11. The students were placed in the same class and therefore, they were mixed ability groups (i.e., enrolled for both the “alternative to Practical’ and ‘Practical Test’). Lena pointed out that the school had a small fund that they used to buy cheaper equipment and chemicals in small amounts. Otherwise, the Ministry of Education is responsible for all the major equipment and chemicals needed at each Government school. Every year the schools need to send in their orders at the end of September and if it is late to place the order then the Government will not help much except for the necessities for the practical examinations. She further also indicated that she received assistance from the Ministry of Education unlike teacher at School A. Generally, the Ministry of Education supplies the school with all the equipment needed for the practical examination at the end of grade 12. According to Lena:

> Even if you have problems throughout the year, and especially if it causes problems that for the end of the year examination, especially for the grade 12’s practical examinations, Higher level, they provide all the equipment for that. We normally just have to say how much we have in stock if we have in stock and if we don’t have them, they will provide them. They make sure about that we have that equipment beforehand. That is also how they assist us but during the year, if there are valid reasons, they do come out and really assist us.

Of interest in Lena’s comments above is that if her school gave valid reasons for additional equipment the Ministry of Education always came to its assistance. If that was the case, and in the face of her belief that even students taking the Alternative test should be exposed to practical work, then why was she contented with a poorly equipped laboratory? Some of the valid reasons she indicated are reflected in the excerpt below:

> Say for instance, I need ten or twenty beakers and I do not have them and is not replaceable with the school development fund, then, we send out a list to the Ministry and then we explain the whole situation to them. And then they buy those things and they provide it to us.

However, the comment below brings out another matter namely, the problem of an overcrowded laboratory. To Lena, "The only other thing that is a problem is that the lab itself is so small. The way it is set up at the moment is also very small, to fit in 42 children. We try but it is a very crampy situation". In addition, Lena also complained about their laboratories that were not upgraded to the level where they could offer practical work at the higher level as prescribed by the Government. The comment below indicates some of the factors that see to impinge on the teaching environment at the school.

> There are advisor offices for specific subjects but I have [not] seen them for two years. I am struggling with them because I gave a report and reasons why they should upgrade our labs because our labs are not up to date according to the science department handbook of 2001. I let them know that it (laboratory) is not up to date so that we can teach Higher level at the school. So, I am trying to get to them so that we can use the donor fund money that is available for such schools. We haven't seen them in two years.

Lena's last comment echoed the need to upgrade the laboratory venues at the schools. She indicated that inappropriate laboratory buildings are not conducive to inexperienced teachers. The Ministry of Education needs to look into these problems as they will affect the students' education on the long run. According to her, inappropriate laboratory buildings hinder the process of teaching and learning in carrying out practical activities effectively. According to her:

> We still experience a lot of problems when it comes to equipment and the building itself. I hope they are going to focus on the building and on the vision of educating scientists. We have a new minister for education now hopefully she will come and look at it [laboratory]. Because things are difficult and I am saying that we are fully equipped but if you are not that experienced and you are not that involved in the subject and you don't know the means and ways to pull through wisely from what you have, and working with what you have and try to copy exactly the same way as what you are supposed to do then you will have problems even if you have to think about having an inexperienced teacher who has never worked in the lab or just try do to, that now all of a sudden this teacher must come and help in the lab and improvise. That makes it difficult [*not knowing how to improvise*] if the building is not well equipped and well-laid out and up to standards.

In summary, Lena's experiences in the above excerpt suggest that some of the dilemmas she encountered emanated from the learning environment such as inadequate equipment, a laboratory that was poorly built, inadequate space, and mixed ability group as well as poor and irregular visits from the Ministry of Education. Certainly, the responsibility of teachers' professional growth, supporting inexperienced teachers and the provision of adequate infrastructural facilities such as laboratories falls squarely on the shoulders of planners in the Ministry of Education.

Although both Christie and Jarijo in School A admitted that they had enough equipment at the school, there seemed to be a pressing challenge of dealing with the running of practical examinations. The laboratories seemed not to be inadequate for the number of students admitted to grades 11 and 12. Also, there seemed to be the need for building larger laboratories in order to allow more students to take practical examinations at the same time. The rotation of groups of students for more than three hours for an examination that was meant to last for an hour did not seem to be functioning well. Figure 4.4 illustrates the set up of School A laboratories for the students enrolled in the Higher Practical examinations.

Figure 4.4: Students writing practical examination in laboratory A

There are fixed and modern working stations with all the needed equipment in School A while the situation at School B is rather pathetic and warrants serious consideration to improve the conditions. The situation at School B is worsened by the laboratory which is not only small but also not built in a modern way. School B needs more laboratories and modern equipment as Lena indicated in the interview. For example, from the classroom observations, all the students enrolled for Higher and Ordinary level at School A took an examination (mid-term test) in practical work while in School B no examination was arranged as the midterm test.

Overall, the teachers involved in the study seemed to be aware of what is needed to conduct practical work. However, there are dilemmas which could be resolved if the education authorities pay more attention to the conditions existing in the schools in terms of the provision of necessary equipment, upgrading the laboratories and supporting the teachers' professional development (e.g. through in-service workshops or further education in higher teacher training institutions). The teachers also need to avail themselves of whatever training they might be given whether organized by government or non-government organization. Besides, they need to align their personal beliefs with the goal of a curriculum in question. Teaching students facing different examinations in the same crowded room does not appear to serve the best interest of such students. Whatever the case, these dilemmas cannot easily be wished away; they require prompt attention by all the stakeholders not least the teachers themselves in the way they make personal efforts to improve their instructional practices.

4.5 Summary

As has been pointed out, Christie, Jarijo and Lena carried out a variety of practical activities and/or demonstrations to enhance the students' practical skills. Christie and Jarijo exposed their students to group experiments while Lena performed teacher demonstrations. In addition, Christie's and Jarijo's students at school A were involved in more complex activities such as individual projects, the production of human organ models, determining land pollution on the school premises, producing improvised equipment while Lena's students in school B were taken to excursions to observe dairy food production and so on.

The three teachers in the two schools conducted a variety of activities aimed at facilitating their students' process skills such as: following procedures, handling of materials and apparatus and recording results. Martinez-Losada and Garcia-Barros (2005) have contended that there are differing views about effective methods for enhancing procedural skills among students. Despite this, it can be argued that Christie and Jarijo created a variety of opportunities for their students to develop high-level process skills. For example, they provided opportunities for designing and carrying out investigative activities where the students were expected to take decisions on the selection of materials and apparatus to be used, why certain procedural steps needed to be taken and others not, what to look for when observing and above all writing reports that would be communicated to various audiences.

There is enough evidence to show that Christie's and Jarijo's students in school A had a better chance of performing well on both simple or complex tasks in terms of deploying appropriate process skills to which they had been exposed in the practical classes as well as assist them in the national practical examination. Lena's students in School B on the other hand had a chance to practise simple skills such as observing, recording observations and drawing conclusions. A plethora of studies has shown that that students involved in inquiry-based learning environments tended to display better scientific attitudes and process skills than those simply observing demonstrations, though the result are by no means conclusive (Acar & Tarhan, 2007; Wu & Hsieh, 2006).

It is apposite to point out that though the students in the two schools faced examinations with distinctly different goals (i.e. practical skills versus alternative to practical biology examinations), the inclusive instructional approaches used by the teachers would certainly disadvantage some of the students. For example, students enrolled for the 'Applied practical skills' examination would have a better chance to practise process skills and have better understanding of practical procedures in group experiments compared to those who were only involved in teacher demonstrations. The findings from a study conducted by Hofstein et al. (2005) are in line with the idea that students involved in carrying out a task may perform better than the group of the students who are not involved. In addition, students enrolled for 'Practical Examination' paper would also be in a better position to carry out practical tasks during examination due to the fact that they carried out the tasks themselves during group experiments compared to those who merely watched teacher demonstrations.

However, there appeared to be fewer or no opportunities organised by the teachers in both schools for the students to use video recordings or computer simulations that would have exposed students to modern ways of doing practical work. Furthermore, there was little or no evidence to show that the teachers in both schools exposed their students to class work where they could have exercised important skills such as drawing graphs and completing tables or studying and understanding biological diagrams, pictures and drawings. The examiners' reports indicate that most candidates are not well equipped with these process skills. It should be obvious that students who lack these skills cannot be expected to display such skills when confronted with examinations demanding their deployment to perform specific tasks. In my observations of the various sessions, there were little or no opportunities for the students to practice how to draw diagrams or graphs to scale. Such exercises would have allowed the students to practise process skills that could have helped them to perform well in the practical examination.

In approaching practical work from the students' perspectives, it seemed that most of the students enjoyed both individual and individual practical activities, discussions and investigations compared to teacher demonstrations or practical illustrations. There seemed to be a need for biology teachers to create a constructivist classroom context or a student-centred environment that facilitates teacher-student-material interactions. Teachers need to focus more on involving students actively in practical work than simply demonstrate skills not easily acquired through spectator experience. Laboratory bench work, discussions, field trips, investigations and exercises are but few examples that can provide opportunities to students to get actively involved in practical activities (Puntambekar & Kolodner, 2005; Wu & Krajcik, 2005).

I observed that all the three teachers practised three types of instructional strategies namely: lecture, group experiments and teacher demonstrations. It is, however, of extreme importance to take into consideration that whatever teaching strategy is chosen by the teachers, it should create opportunities for students to participate actively in practical activities.

All the three teachers presented lectures that centred on developing different biology concepts. During lecturing, Christie demonstrated interactive patterns of teaching while Jarijo and Lena exhibited authoritative patterns of interactions with their students. Authoritative interactional patterns of instruction tend to prevent students from taking part in discussions of various aspects of biology freely. In other words, Jarijo and Lena seemed to exhibit restrictive behaviours that could prevent students from interrogating the presented content. Chin (2006) posits that authoritative patterns of interactions have a restrictive effect on students' thinking and to minimize the role of teachers and students in the co-construction of meaning. By using an authoritative teaching style, Jarijo and Lena appeared to practise the question-and-answer strategy that can restrict students from talking or reflecting as should be the case in a classroom/laboratory discourse. In other words, Jarijo and Lena used closed-ended questions that made students to provide only simple answers that depend on recall rather than high-level answers requiring analysis or evaluation. In addition, Jarijo and Lena hardly used other teacher interventional strategies such as sharing ideas, shaping students' ideas, making key ideas or stressing main ideas to students as well as to checking on students' ideas. However, Chin (2006) has suggested that such an authoritative approach could be meaningful if teachers apply further supportive dialogues.

Christie using an interactive patterns, attempted to involve her students in discussions by posing more open-ended questions. In turn, this allowed her to use a variety of teacher interventional strategies such as sharing students' ideas with the whole class, shaping students' ideas to be more scientifically oriented, checking students' understandings and making key ideas available by highlighting the main scientific aspects of the content as well as reviewing students' previous knowledge. I concur with Oh (2005) who suggested that interactive patterns of instructions tend to make scientific knowledge available to students and to enhance their performance. In addition, teachers tend to scaffold learning meaningfully and to coach students to manage their learning meaningfully. This is also in agreement with the findings of a study conducted by Acar and Tarhan (2007). They found that the cooperative learning method was more successful than the traditional method in remedying predetermined misconceptions.

Christie and Jarijo exposed their students to group experiments. During the group experiments, the focus was on student-student-material interactions. The patterns of interactions in the groups were in some cases dominated by one or two students while the others were inactive. In the large groups the shy students were passive and seemed to be excluded from the teaching-learning process.

It was observed that members of the groups focused their discussions on different process skills such as procedural (handling materials, apparatus) and conceptual (observation, interpretation and making conclusions) skills. Such student-student discussions helped them to create a platform where they were able to talk about the procedures, implemented division of labour as well discussed about observable results. They were also able to agree or disagree about the outcomes of the results. Thus, group experiments seemed to involve the students actively in discussing procedural skills in terms of what or not should be observed and to make sense of the results observed.

Teacher demonstration was the main instructional method used by Lena. Following from her interaction patterns, Lena seemed to reveal an authoritative style. There is enough evidence that shows that Lena seems not to provide enough opportunities to students to be actively involved in developing process skills except to observe, record results and to write conclusions. Thus, passive learning took place due to Lena's questioning style.

The implications for science teacher educators and the Ministry of Education are:

- The need to train science teachers about student-centred instructional approaches that will allow them to extend their knowledge in scaffolding and appropriate students' learning in practical work (Chin, 2006).
- Developing science curriculum that will enhance the teaching of practical work in a student-centred environment.

- The need to create new avenues in order to reflect on teacher training that will foster a greater awareness of the notions and values of teacher interventional strategies (Morge, 2005).

Overall, the three teachers seemed to have diverse views and beliefs about practical work that impact on their teaching styles. Some issues that emerged from the interviews and classroom/laboratory observations relate to: (i) the school context (i.e. the constraints arising from the physical situation and resources available; (ii) financial constraints; and (iii) the limited support teachers received from subject advisors. These factors seem to have a direct impact on the decisions that will be taken in order to involve students in different practical activities.

Although the students appeared to have positive views about practical work, both groups of students (in schools A and B) indicated that they wanted to carry more practical work and spend more time doing practical activities in their respective schools. Teacher-assisted demonstrations seem to disadvantage those students who assist the teachers. The students appeared not to take part in the discussions (if any), listen to the teacher or record observations when necessary.

Chapter 5

Conclusions, Implications and Recommendations

5.1 Introduction

The study explored the nature of practical work in biology education in two Namibian secondary schools. In particular, it sought to determine: (1) the nature of practical activities carried out by the three biology teachers in the two schools; (2) the types of instructional strategies they used; and (3) the perceptions they held about practical work and how these might have influenced their instructional practices relative to the way they prepared their students for practical examinations.

The study was underpinned by personal and social constructivism as espoused by Piaget and Vygotsky and to some extent Ausubel. Social constructivism embraces the notion of active learning or student-centred instructional practices in contradistinction to a teacher-dominated instructional approach. Both personal and social constructivists' learning theories were used as a backcloth to analyse laboratory/classroom interactions during practical work or demonstrations in school biology. According to the constructivist perspective students develop knowledge and scientific understanding both individually and socially (Boz & Uzuntityaki, 2006; Chin, 2006; Leach & Scott, 2000; Vygotsky, 1978). Although learning is ultimately an individual process it also involves the linking what one has learned to what has already been known or proposed by others in one's community. Secondly, the students construct new knowledge through social interactions (Liang & Gabel, 2005; Oh, 2005; Shepardson & Britch, 2006).

The study employed mainly qualitative research methods to collect and analyse data. This entailed the use of interviews, document analysis and classroom observations. The purposive sample consisted of three teachers and their students in two secondary schools in Namibia. In the following section, I will first provide a summary of the major findings of the study and then highlight their implications for policy, curriculum development, instructional practices and research. Recommendations and suggestions for future studies will then be presented.

5.2 Summaries of salient points

The main points are presented according to the research questions stated in Chapter 1. For ease of reference, the findings from teacher and the students' interviews and observations as well as evidence based on document analysis are summarized.

5.2.1 Research question 1: What practical activities do Namibian Biology teachers use to develop investigative and procedural skills among their students?

Major findings

As indicated in Chapter 4, the two most frequently used types of practical activities were in the form of group work and teacher demonstrations. The points listed below reflect the way these two types of activities were carried out in the two schools:

- The teachers, especially Christie and Jarijo in School A appeared to expose their students to diverse types of practical activities that included simple activities such as handling equipment and materials as well as observing events/phenomena in the laboratory to more complex activities such as projects (that form part of investigations) and the production of models that focused on body organs such as eye, ear, brain, cell models. The list of practical activities seems to concur with other scholars' practical activities except that Christie and Jarijo seemed to involve their students less in field trips and simple exercises that could have allowed the students to practise how to plot graphs, make drawings, the use of computer simulations or video recordings (Brown, 1995; Millar et al., 1999; Parkinson, 1994; Woolnough, 1994; 2000). Activities such as biological drawings, construction and interpretations of graphs, computer simulations, analyzing data or writing laboratory reports and the like were hardly conducted at both school sites. Similarly, du Plesis et al. (2003) posits that there is a need for the students to acquire practical skills such as drawing, graphing, speech illustrations, hierarchical illustrations and real images because such visual representations are used regularly in examination papers. Thus, it is not strange that the MEC, Examiners' Report (2006; 2007) showed that practical examinations remained the biggest challenge within the Namibian education system. Students continue to have problems in performing successfully in practical examinations due to lack of high-level procedural and conceptual skills.

- Some practical activities such as fieldtrips, dissection of animal and plant tissues or organs, or activities demanding both manipulative and high-order skills were hardly carried out at the grade 11 level at both schools due to lack of time and teaching overload. For example, practical skills such as designing and planning activities as well as engaging students in critical thinking, evaluating ideas and negotiating and reaching consensus did not feature in the implemented practical activities at grade the 11 level.

- Christie and Jarijo in School A with enough resources arranged practical activities over a period of time in order to prepare their students for practical examinations in grade 12 level. For example, the students conducted practical work as from grade eight to grade 12 as compared to Lena in School B with fewer resources. The availability of laboratory resources seemed to have a stranglehold on practical work. Teachers may decide to teach in certain manner due to lack of resources. Other scholars (Crawford, 2007; Lotter et al., 2007; McNeil & Krajcik, 2008; Verjovsky & Walddegg, 2005) seem to maintain that there are various reasons why teachers might practise what they believe in.

- Students, especially in School A, produced some improvised equipment by using local materials at home or around the school premises as a part of their practical work as compared to the students at school B. Other studies (Motloutsi & Dekkers, 2003; Tlala, 2006) have indicated that such materials might increase the students' level of learning in terms of the acquisition of knowledge, procedural and investigative skills as well as create high a level of interest and curiosity among students. Christie and Jarijo used improvised equipment to teach in a particular manner that could not be taught in another manner such as the collection of cigarette remains as examples of land pollution.

- The students involved in practical activities seemed to have a better chance of practising the intended practical skills in the NSSC H- and O-Level Biology syllabus than the students exposed to teacher demonstrations that provided fewer opportunities for the students to acquire most of the procedural and conceptual skills.

- Both Christie and Jarijo used demonstrations only when equipment or materials were scarce while Lena performed experiments once in a while to deepen her students' conceptual understanding of topics that might feature in the Practical Examination. However, the case of Lena seemed to be different from what has described by Parkinson (2002). For food testing Lena did not need a lot of resources and there was no danger in performing the practical activities.

- Evidence from the study further suggests that teacher demonstrations that were carried out only allowed the students to observe and to record and draw conclusions of what they observed from memory. There seemed to be a mismatch in organising appropriate practical activities that could have prepared students for both types of practical examination and what teachers and students did in the real classroom/laboratory setting. In teacher demonstrations and assisted teacher demonstrations learning outcomes about process skills seem to be hidden under the guise of teacher-student demonstrations while in reality most of the students were idle or deprived of hands-on experiences. This appears to be one of the shortcomings of teacher demonstration as well as the assisted teacher demonstrations.

- The three teachers involved in this study namely, Christie, Jarijo and Lena conducted a variety of practical activities in their respective schools which reflected the contexts in which they worked as well as their teaching experiences. For example, both Christie and Jarijo teaching in School A had well resourced biology laboratories while Lena in School B had no such luxury. The specific activities organized by the teachers ranged from handling equipment and materials and observing events/phenomena in the laboratory to more complex activities such as projects (that form part of investigations) and the production of models that focused on body organs such as eye, ear, brain, cell models, etc.

- Christie in school A, who prepared her students for both the Higher and Ordinary Level practical examination emphasised group experiments while Lena from School B whose students would be sitting for both the Higher and Ordinary Level practical examination emphasised mainly teacher demonstrations. While Jarijo in school A whose students would be sitting for the O level applied practical skills emphasised group experiments like Christie. But whatever method the teachers used the final examination seemed to be the driving force (e.g. Bennett, 2003; Fabiano, 1998; Harlen, 2000; Ogunniyi, 1986, 1996; Rollnick, 1998b; Savage, 1998).

- Although Christie and Jarijo, (probably as a result of Christie's mentoring), shared a common perception of practical work they differed in the reasons they adduced for using group experiments. For example Christie's reasons for using group experiment were based on the availability of teaching materials such as real specimens for dissection and other rare materials as well as financial reasons while Jarijo's reasons were based on social reasons. Jarijo felt that it was necessary that the students were allowed to interact and communicate with one another during group experiment. She further considered working alone as being intimidating to the students.

- Although the students were taught in basically the same way, group experiments seemed to offer more opportunities to students writing the ‘Practical Examination’, that is, those enrolled for H-level biology examination have the opportunity to practise the intended process skills compared to teacher demonstrations or teacher assisted demonstrations that seem to be focused on developing simple process skills.

- Both schools seemed not to provide opportunities to the students to complete exercises that could assist them in acquiring some other important skills such drawing graphs, completing tables, understanding biological diagrams and pictures as well as making drawings. In addition, microscopes seemed to be under-utilized in both schools. Besides, many topics in the syllabus do not seem to encourage the teachers to expose their students to the use of microscopes.

Implications

The implications of the findings reported and discussed in Chapter 4 for the science education is twofold namely, teacher training and the improvement of leaning environment in an attempt to improve students’ performance in practical work. In this regard:

- Teacher education programmes need to be reformed alongside the school curriculum in order to equip science teachers with desirable skills for conducting practical work. Teacher education programmes should include ideas on how to involve students actively in the learning process.
- Teacher education programmes should focus on teaching science teachers on how to transform practical tasks and make them accessible to students. The programme should focus on improving on teacher interventional strategies to broaden the scope of student-centred approach.

- There is a need for the Ministry of Education and schools to design teaching and learning laboratories that will motivate students to develop important attitudes of doing practical work (Wu & Krajcik, 2005).

Implications for science teacher educators and the Ministry of Education include the need to:

- Train science teachers about student-centred instructional approaches that will allow them to extend their knowledge in scaffolding and appropriate students' learning in practical work (Chin, 2006; Gregory, 2002).
- Develop science curriculum that will enhance the teaching of practical work in a student-centred environment.
- Create new avenues in order to reflect on teacher training that will foster a greater awareness of the notions and values of teacher interventional strategies (Morge, 2005).

5.2.2 Research question 2: What types of instructional strategies are used by the Biology teachers to prepare their students for the practical examination?

As the findings under question 1 above show, the main instructional strategies used were group work and teacher demonstrations complemented with explanations in the form of lectures in order to prepare the students for practical examinations at grade the 12 level. The key points are presented below according to the three modes of instructional strategies:

(a) Lectures

The preponderance of lectures as an instructional method in most classrooms is perhaps a worldwide phenomenon. The role of lectures as a preliminary activity to doing practical work had already been discussed in Chapters 2 and 4 and would not be repeated here. However, in view of the fact that most of the students lack the basic understanding of the concepts involved in many scientific processes (Millar et al., 1999; Narayan & Wallace, 2003; Ogunniyi, 1986a; Westbrook & Marek, 1992) teachers need to provide meaningful and extended explanations before engaging students in practical work. Meaningful discussions can take place as complementary activities in practical work as well. Otherwise, students are likely to waste a lot of laboratory time asking incessantly routine questions which they ought to have known or read in their attempts to get some hints about what or not to do in a given practical activity.

The tendency for students to follow laboratory manuals step-by-step like a cook book recipe is a reflection of deficiency in their conceptual understanding or procedural skills. However, if during the theoretical class, the teacher has taken sufficient time to explain the underlying concepts or principles such an unwholesome dependence on the laboratory manual might be unwarranted. As Tsai (2006) noted, many students laboratory work means the manipulation of equipment but not manipulation of concepts and principles.

There is also the tendency for teachers to operate in a certain ways that might promote or inhibit teacher-student discussions (Watson, Swain & McRobbie, 1999). For example, Christie lectured in an interactive manner and used teacher questions as a spring board to discuss some aspects of practical work. Christie used open-ended questions to probe students' understanding about practical work and other relevant content knowledge. Question-and-answer interventional strategy appeared to create a more interactive environment and Christie used this opportunity to share, shape, select and review ideas with the students. On the contrary, Jarijo and Lena seemed to have an authoritative instructional style that diminished teacher-student interactions as well as reduced discussions at the social inter-plane level. Jarijo and Lena used close-ended questions that did not probe thinking in students. The students in Jarijo and Lena' classes needed to answer simple recall questions compared to Christie's use of open-ended questions that were mostly at different levels of complexity (Welzel, von Aufschnaiter & Scholster, 1999).

Other teacher interventional strategies used were to: shape, share, select, review ideas and make key ideas. These interventional strategies seem to be linked to the teachers' style of questioning. Open-ended questioning style seemed to create a platform for Christie to be engaged more with her students than Jarijo and Lena who used a closed-ended questioning style. An interactive instructional style can create a platform where students are actively involved in discussions with teachers.

(b) Group Interactions

The discussions that often emerge during group interactions can play a vital role in enhancing students' understanding of the underlying concepts or principles which in turn, could facilitate the development of such process skills as observing and comparing objects or events, measurements of objects, events or physical effects, sorting and classifying objects, using appropriate equipment, concepts, symbols or conventions; assigning valid meanings to scientific facts, making claims or taking decisions based on sound reasoning, and writing scientific reports (Ogunniyi & Mikalsen, 2004).

As stated before, group experiments seem to actively involve the students in discussions compared to teacher demonstration where the students seemed to be deprived of active involvement in performing practical tasks as based on their level of understanding (Welzel et al., 1999). It was observed that discussions in group experiments focused on understanding procedural and conceptual process skills. Students discussions centred on helping one another to carry out procedures, to make decisions on who should carry out which duty as well as talking about what needed to be observed.

The writing of scientific reports based on observations during practical work is an invaluable process skill. It is not a skill that comes that readily. It involves the use of both basic and high-order cognitive skills such as: recording information accurately; interpretations of information; exploring and analysing data critically; drawing inferences; communicating scientific information in a comprehensive way; etc. (DOE of South Africa, 2002; Ogunniyi & Taale, 2004). However, the teachers involved in this study hardly discussed how to write scientific reports. Generally, Christie and Jarijo used laboratory manuals and Lena used self-developed worksheets. Thus, there was no need for the students to write reports but they simply completed the blank spaces in the manuals.

(c) Teacher demonstrations

In Chapter 4 the issue of teacher demonstrations was discussed in detail. What has emerged from that discussion which is worth being highlighted in this chapter is listed below:

- With teacher demonstrations, it was found that Lena performed most of the process skills followed by the students who assisted her. The rest of the students seemed to have been left out as there were inadequate opportunities for them to partake in exercising the intended process skills. The students did not seem to be involved in critical process skills such as: (i) following sequence of instructions and using/handling apparatus, materials and techniques; (ii) making and recording estimates and measurements; (iii) planning, designing, carrying out investigations and suggesting modifications in the light of experiences. She did not empahasize these skills during the teacher demonstrations that I observed.
- As indicated in Chapter 4, Lena seemed to have an authoritative teaching style. Most of her interventions took place in the form of reading the procedures and showing the end results of the demonstrations. Thus, no discussion took place whereby the students could negotiate the outcomes of the experiments. Thus, these were some of the ways in which the teacher (Lena) could influence student-discussion in favour of her teaching strategy (Watson et al., 1999). Although Lena seemed to have a comprehensive conception of what practical work entails, her classroom practices seemed not to include her good intentional ideas about

practical work. In addition, the least occurring teacher interventions seemed to be the explanations of ideas or observations and provision of classroom discussions.

- A considerable number of students in both schools seemed to encounter problems in identifying colours or making meaningful observations or recording results when teacher demonstrations were conducted. They tended to record incorrect results for most of the food tests except for the test for starch followed by the test for fats and oils.

The implications of the above for science teacher educators, curriculum planners and policy makers include the need to:

- Train science teachers on how to make teacher demonstrations more interactive and student-centred so they acquire conceptual and procedural skills demanded by the new curriculum in Namibia (Chin, 2006).
- Orient prospective and practising teachers towards the critical outcomes enunciated in the new curriculum through regular seminars and workshops.
- Involve teachers in the curriculum development process so that they can gain necessary knowledge about the aims of the curriculum as well as develop practical, technical and emancipatory knowledge (Ogunniyi, 1996; Ogunniyi & Mikalsen, 2004).
- There is the need to create new avenues in order to reflect on teacher training that will foster among teachers a greater awareness of the nature of classroom/laboratory interactions as well as the values of such interactions in the teaching-learning process (Millar et al., 1999; Morge, 2005; Narayan & Wallace, 2003; Ogunniyi & Mikalsen, 2004; Ogunniyi & Taale, 2004).

5.2.3 Research question 3: What are the Biology teachers' views and beliefs about laboratory work and how do such views and beliefs inform their instructional practices in the Biology laboratory/ classroom?

The views and beliefs of Christie, Jarijo and Lena about laboratory work had already been presented in Chapter 4. The list summarized below is reflects of their perceptions of laboratory activities and how such perceptions might have informed their instructional practices:

- Christie and Jarijo in School A with enough resources arranged practical activities over a period of time in order to prepare their students for practical examinations in grade 12 level. For example, the students conducted practical work as from grade eight to grade 12 compared to Lena in School B with fewer resources. The lack of essential laboratory resources tended to limit how much practical work could be done.
- The scarcity of resources is a policy issue and the Ministry of Education cannot play the ostrich here, though one is not unaware that even when resources are available, teachers may still resort to the traditional chalk-and-talk method of instruction (Ogunniyi, 1996; Ogunniyi & Taale, 2004). Christie is perhaps an exception in this regard. She only organised teacher demonstrations when teaching resources for dissections became depleted or when buying such equipment and resources became expensive. Lena's situation was more of the lack of resources at the school. Thus, financial constraints as well as overcrowded classrooms were alluded to by the three teachers as obstacles which hindered them in arranging practical work in the way they would have liked. Nevertheless, their conceptions of practical work seemed to be directly impacting on the way they organized and taught practical work.
- The teachers seemed to show diverse conceptions of practical work. Their conceptions of practical work seemed to have some impact on the way they organized and taught practical work (Haney & McArthy, 2002; Tsai, 2006).

- The diverse views about practical work expressed by the teachers seemed to be related to their personal beliefs and the contexts of the schools in which they worked (Haney & McArthy, 2002; Tobin et al., 1990; Tsai, 2006). For example the views and beliefs expressed by Christie and Jarijo working in better resourced laboratories seemed to coincide more with their instructional practices than Lena who worked in a less resourced laboratory.
- The students appeared to have positive views about the way practical work was conducted was conducted by their teachers. Further, those who were involved in teacher demonstrations wanted to carry out practical activities themselves rather than to merely observe the teacher demonstrations. They argued that they would have developed a better understanding of what they were exploring if they had actively been involved in practical tasks while those who were in Lena's demonstration sessions seemed to be disadvantaged in many ways (Osborne & Collins, 2001). For example, they did not seem to take part in the discussions or listen attentively to the teacher's explanations. Likewise, they felt that they were left out and only saw the end results of the demonstrations.

The implications of the above findings are certainly worthy of closer consideration. For ease of reference, the implications for policy, curriculum development, instructional practices and research are highlighted in the section that follows.

5.3 Implications for policy and curriculum development

According to Roberts, "Practical work is a means to an end; it is not an end in itself any more than discussion or debate is an end" (2004, p. 113). There seems to be a need to align practical work with what is being examined at the end of grade 12 level. According to du Plesis et al. (2003), semiotics are used in practical examinations in particular the 'Alternative to Practical' examinations. Semiotics, then, becomes a part of the nonverbal resource tools that teachers use in making meanings about scientific knowledge and processes. However, if teachers are unskilled in the use of such a vital tool (e.g. through workshops organized by the examination and curriculum divisions of the Ministry of Education) how can they be expected to integrate it into their instructional protocols? As Ash et al. (2007) had noted, language is a 'pre-eminent tool for learning and teaching' (p. 1581). Meaning making in science classrooms, then, involves more than a mere verbal communication of scientific knowledge (Scott & Jewitt, 2003).

- **Variety of practical activities with the purpose of developing high-order process skills**

The organization of a variety of practical activities that would lead to the development of process skills as enunciated in the curriculum presupposes that teachers have been properly oriented towards the attainment of such a goal. Without the involvement and adequate support from curriculum planers, subject advisers and examination personnel, it would be difficult if not impossible to expect an inexperienced teacher like Jarijo or even an experienced teacher like Christie to automatically implement the aims of the new curriculum. One, of course, would also assume that the examination questions would reflect the new emphasis on students displaying essential process skills rather the usual regurgitation of facts as has been the case for decades (Ogunniyi, 1986; Ogunniyi, 2007b; Ogunniyi & Mikalsen, 2004; Ogunniyi & Taale, 2004). The stranglehold effect that examinations have on the curriculum has been pointed out. There is also a need to involve students in extended open-inquiry practical activities. Some studies (Acar & Tarhan, 2007; Lake, 2004; McCarthy, 2005) noted that students in cooperative classrooms tend to perform better than students taught with traditional or demonstration methods. In other words, students seemed to need multiple forms of support and multiple learning opportunities (Puntambekar & Kolodner, 2005). There is a need, then to create dynamic complex teaching and learning environment in order to support both minds-on and hands- practical activities (Wu & Krajcik, 2005).

- **Alignment of the teaching of practical skills with the requirements for the assessment of practical work.**

An alignment of practical work with what is examined at the end of grade 12 level seemed to be greatly needed. Semiotics are used in practical examinations in particular the ‘Alternative to Practical’ examinations. Semiotics, then, become a part of the nonverbal resource tools that teachers use in making meanings about scientific knowledge and process. Ash et al. (2007) consider language as the ‘pre-eminent tool for learning and teaching’ (p. 1581). Meaning making in science classrooms, then, involves more than a mere verbal communication of scientific knowledge.

Science teachers use many objects including their bodies in order to make meanings about what is taught (Anderson, Zuiker, Taasoobshirazi & Hickey, 2007; Mortimer & Scott, 2003; Wickman & Ostman, 2002). Semiotics such as diagrams, tables and graphs are used in science papers, teaching platforms and in examination papers. For example, in biological laboratory, teachers use diagrams intensively to illustrate procedures in carrying out certain practical tasks (Scott & Jewitt, 2003).

The alignment of practical activities to the practical examination might minimize the misinterpretations of the role of school science laboratory work as well as finding appropriate ways of examining process skills (Duggan & Gott, 2002) in the ‘Alternative to Practical’ as compared to the ‘Practical Test’ examinations. Designing teaching and learning laboratory manuals that will differentiate between the requirements for the teaching of ‘Alternative to Practical’ and ‘Practical Test’ as well as differentiating between the difficulty levels of the different practical tasks for different ability students, that is, the teaching of Higher- and Ordinary levels in the same classroom, becomes a necessity.

- **Development of appropriate teaching and learning materials**

The study points out the need to develop teaching and learning materials for practical work that will involve students in carrying out differentiated practical activities. Students need to be involved in practical activities that will enhance their acquisition of higher-order process skills rather than the lower-order thinking skills (Lake, 2004; Piggott; 2002; Savage, 1998). Sometimes some form of data-handling that was never used in class is examined extensively in the end of year practical examinations (Keiler & Woolnough, 2002).

5.4 Recommendations

In the light of the findings and the implications highlighted above, the following recommendations are made for future research. There is need to:

- Use a variety of practical activities to engage students in practical work to acquire different kinds of knowledge, process skills and practical experiences as future biologists (Gott & Mashiter, 1991).
- Align practical activities with the aim to minimize the misinterpretations of the role of school science laboratory work as well as finding appropriate ways of examining process skills in the 'Alternative to Practical' compared to the 'Practical Test' examinations.
- Design teaching and learning laboratory manuals that will differentiate between the requirements for the teaching of 'Alternative to Practical' and 'Practical Examination' as well as differentiating between the difficulty levels of the different practical tasks commensurate with different learning abilities.
- Equip teachers with instructional skills that will enable their students to acquire higher order thinking and practical skills.

5.5 Suggestions for future research

The study has highlighted the importance of research to determine the following crucial issues relating to practical work in school biology in Namibia. There is the need to:

- Conduct a longitudinal study that would shed more light on the nature of biology practical work in Namibian secondary classes. Such a study should include both the junior and senior levels and should include both the Life Science (grades eight to ten levels) and Biology (grade 11 and 12 levels). The findings of such a study could be used to inform teachers and curriculum designers about the effectiveness or otherwise of practical work in the Namibian classrooms.
- Develop at both the University and the Colleges of Education levels programmes that could help equip prospective and practising biology teachers with essential instructional skills on how to organize practical work. The educational programmes need to focus more on providing teachers with innovative teaching strategies which will be informed by recent research in the field of Science, Mathematics and Technology Education or other relevant fields.
- Teacher educators should carry out research at classroom level in collaboration with Biology and Life Science teachers who are willing to partake in the studies on a small scale in order to inform science, Mathematics and Technology teachers about their instructional practices. This should be done with an eye to improve both the discipline and pedagogical knowledge of prospective and practising teachers.

The two schools under study have graphically demonstrated both the merits and demerits of group practical work and teacher demonstrations as instructional strategies for enhancing students' acquisition of critical process skills. As was pointed out in Chapter 4, a plethora of studies have shown that both methods have their strengths and weaknesses. In the final analysis, it seems that the school context in terms of teachers' beliefs and practices as well as the learning environment that tend to dictate what instructional protocols are most suitable.

5.6 Concluding statement

As far as I am aware, this study is the first in-depth study of its own kind in Namibia that has been carried out to explore the teaching, learning and instructional practices of practising Biology teachers in practical work. In other words, and to the best of my knowledge, there has been no other study specifically concerned with determining the nature of biology practical work in Namibian Senior Secondary Schools.

The study was motivated by comments that teachers in biology receive each year from the Directorate of Examinations in Namibia about the students' performance in practical examinations. Similar comments are written each year and send to schools but it seems that teachers do not pay sufficient attention to the report. As a teacher educator with an interest in educating biology teachers, I wanted to find out where the problems seem to lie.

Many challenges were encountered throughout the duration of the study such as:

- As a young researcher I had little experience in carrying out research studies warranting the details and intensity expected at this level of education.
- Teaching duties made it very difficult for me to collect and complete the study on time.
- Many biology teachers were not interested in having someone in their classrooms on a daily basis studying them. Hence, they refused to take part in the study due to lack of knowledge about research studies. In addition, those who volunteered earlier later declined participating in the study after finding

out about the time and level of involvement called for by the study. Some needed to attend workshops on a regular basis to upgrade them.

- Although I did not experience problems with students who volunteered, they seemed to provide only shallow information when questions centred on their teachers.
- Sometimes the teachers mentioned some good ideas that I needed to explore further. Thus, a one trimester was not enough to collect information on practical work. Sometimes teachers did not organize practical activities for the whole trimester or arranged a few sessions per term.

Practical work is not as rosy or spotless as it seems to be. There are lot of challenges that teachers need to consider when planning and organising practical work. Challenges seem to be linked to the conditions existing in the different school contexts as well as the knowledge of teachers responsible for the teaching of practical work. Constraints might be inavailability of resources, inadequate laboratory space, school culture, working spirit of the teachers and students, inadequate support from authorities, financial needs of the schools and lack of strong student support system in schools. All these factors are important in establishing a reasonable functioning laboratory environment. But despite the challenges and constraints encountered in the study, it is my hope that the findings would prove to be informative and useful for future studies in the area. The whole experience has not only enlarged my intellectual horizon, it has certainly increased my awareness about the intensity and commitment required to carry out an in-depth qualitative study of this kind.

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APPENDIX A

REPUBLIC OF NAMIBIA

MINISTRY OF EDUCATION
KHOMAS REGION

Tel: (09 264 61) 2939411
Fax: (09 264 61) 231367
Enquiries: T.L. Shivute

Private Bag 13236
Windhoek

File No.: 12/2/4/4/2

9 May 2006

Mrs H.U. Kangjeo-Marenga
Depaltment of Mathematics, Science and Sport Education
UNAM
P/Bag 13301
WINDHOEK

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

Your letter dated 5 May 2006with the above mentioned request has reference.

You are hereby given permission to conduct a research in Practical work in Science education at the following government schools: Academia; A. Shipena; Centaurus Concordia College; Dawid Bezuidenhout; Delta; Jan Mohr and St. Joseph's Secondary Schools on condition that:

a) arrangements should be made with the Principal before hand
b) those teachers who will be interviewed should do so voluntarily
c) the interview should not disrupt the school programme/classes
d) a copy of the final report should be provided to the Khomas Education Region

St Paul's College is a private school; therefore, you have to approach the school Principal to allow you to do research at his school.

We wish you success in your research.

Yours sincerely

MINISTRY OF EDUCATION
P/BAG 13236 WINDHOEK
09 MAY 2006
KHOMAS REGION

MS C.U. TJIKUUA
DIRECTOR: KHOMAS REGION

ALL OFFICIAL CORRESPONDENCE MUST BE ADDRESSED TO THE DIRECTOR: KHOMAS REGION

APPENDIX B

PRE - PRACTICAL INTERVIEW PROTOCOL Pre-PIP)

No:
Sex:
Age:

1. What comes to your mind when you hear the phrase "practical work"?
2. What types of practical work do you like the most? Rank order your choices by ticking (√) from what is most liked (1) to less liked (9):

	Tick here
Demonstrations	
Illustrations	
Exercises	
Laboratory work	
Investigations	
Field work/Trips	
Manipulate materials/ apparatus during practical work	
Record experimental results and observations	
Discussions to find solutions to the problem	
Any other (specify)	

3. Explain why you like these practical activities the most.
4. List the practical activities that you carried out.
5. What are your general concerns about the teaching of practical work in your school?

Thank the individual for participating in the interview.

APPENDIX C

POST – PRACTICAL INTERVIEW PROTOCOL (Post-PIP)

NO:
Sex:
Age:

1. What are your views/ feelings about the teaching of practical work in your school?
2. What are your views/feelings about demonstration?
3. What are your view/ feelings about working in group experiments?
4. Which way do you think you will learn better? Is it through demonstration or textbook lecture about laboratory work?
5. In your own words, what would you like your teacher to do when carrying out practical work?
6. What are your general concerns about the teaching of practical work in your school?

Thank the individual for participating in the interview.

APPENDIX D

TEACHER INTERVIEW PROTOCOL

1. Can you give me little background information about yourself, who you are and what your do?
2. What comes to your mind when you hear the word "practical work"?
3. What types of practical activities do you like to involve your learners in most of the time? Explain why?.
4. What practical activities do your learners enjoy the most?
5. Explain to me how you prepare your learners for practical work.
6. Tell me, what is it that you expect from your learners to do when they carry out practical activities?
7. What do you do in order to find out if the experimental results recorded by learners are correct or wrong?
8. What do you do in order to assist your learners during practical work?
9. What do you do when learners do not finish their tasks in time?
10. Do you prefer group experiments or learners to work individually on practical task? Explain.
11. What problems do you experience in teaching practical work to learners?
12. Do you teach mix ability groups, e.g. high- or ordinary level?
13. What activities do give them? Similar or different activities?
14. What difficulties do you experience in testing or assessing learners' practical abilities and skills?
15. Tell me, what do you do to teach learners all the practical skills and abilities?
16. What type of assistance do you get from:
    a. Examination officers
    b. Clusters
    c. Subject advisors
    d. Any other (specify) ________________

APPENDIX E

<u>Practical 19</u>

<u>To test for starch</u>

Apparatus

Test-tube rack, 5 test tubes, teat pipettes, iodine solution, starch solution, glucose solution, egg solution, fat suspension

What to do:

1. Label the five test-tubes, 1-5.
2. Put 3ml of each solution into the test-tubes.

   Starch into test tube 1

   Glucose into test tube 2

   Egg into test tube 3

   Fat into test tube 4

   Water into test tube 5
3. Use your pipette to add 3 drops of iodine solution to each test tube.
4. Shake each test tube from side to side, not up and down, to mix the contents.
5. Look for any colour change apart from the yellow colour of the iodine solution itself.

Results:

1. Complete the table of the results.

Tube	Substance	Reaction with iodine
1	**Starch**	
2	**Glucose**	
3	**Egg**	
4	**Fat**	
5	**Water**	

2. What color does the mixture go when there is a positive reaction?
3. Which of the samples gave the most striking colour change?
4. To which main class of food substances does starch belong?
5. Why where the other samples included?
6. What was the point of having test-tube 5 as part of the experiment?

APPENDIX F

Practical 20
To test for a sugar such as glucose
(reducing sugar)
Apparatus
5 test tubes, test-tube holder, test tube rack, pipette, Bunsen burner, tripod, gauge, water bath, Benedict's solution, 5 test solutions (same as in P1) P1= practical 1
What to do:

1. Prepare a water bath with boiling water.
2. While the water bath us getting ready, mark your test tubes 1 – 5.
3. Put 3ml of test solutions into the test tubes as in P1.
4. Add 10 drops of Benedict's solution to each test tube.
5. Place all test tubes into the water bath. The water bath should be kept at a slow boiling point.
6. Leave for 3 – 5 minutes.
7. Turn off the Bunsen burner. Put test tubes back into the test tube rack and observe.

Results:

1. Complete the table of the results.

Tube	Substance	Reaction with iodine
1	Starch	
2	Glucose	
3	Egg	
4	Fat	
5	Water	

2. What colour changes tool place when Benedict's was added to each test tube at the beginning of the experiment?
3. With which food group does Benedict's give the most striking colour change?
4. Apart from the colour, what other changes took place?
5. What is a reducing sugar?

APPENDIX G

<u>Practical 21</u>
<u>To test for sucrose</u>
(non-reducing sugar)
Apparatus
Same as in P2
What to do:

1. Get a water bath to boiling point and keep it at just boiling point.
2. Use test tube 1 – 3.
3. To tube 1 ass 2ml sucrose solution, Use your pipette to add 3 drops of iodine solution to each test tube.2 drops of dilute hydrochloric acid and place into water bath for 2 – 3 minutes.
4. In tube 2 place 2ml sucrose solution.
5. In tube 3 place 2ml water and 2 drops of hydrochloric acid.
6. After tube 1has been in the water bath for 3 minutes, add 10drops of Benedict's solution to each of the three test tubes.
7. Place all three test tubes back into the water bath for 2 – 3 minutes.

Results:

1. Fill your results into the table below:

Tube	Treatment	Colour change
1	**Sucrose + HCl boiled**	
2	**Sucrose**	
3	**HCL**	

2. In tube 2, did the sucrose react?
3. Give an explanation for your answer in 2.
4. How does sucrose need to be treated before it reacts to Benedict's solution?

____
____
____
____

APPENDIX H

Practical 22
To test for proteins (Biuret test)

Apparatus
Same as in P1/P2

What to do:

1. Follow steps 1 + 2 from P1.
2. Use your pipette and add 5 drops of sodium hydroxide solution (Fehling B solution) to each test tube.
3. Shake each test tube side to side.
4. Add 5 drops of a copper sulphate solution (Fehling A solution) to each test tube. Shake each tube again.
5. Wait 1 minute and then look at the colour change in each.

Results:

1. Complete the table below:

Tube	Substance	Result of Biuret test
1	Starch	
2	Glucose	
3	Egg	
4	Fat	
5	Water	

2. What colour change was there with the egg solution?
3. To which main food substance does egg belong?
4. What was the use of test tube 5?

APPENDIX I

Practical 23

To test for fats

Apparatus

Same as before.

What to do:

1. Use test tubes 1 - 4.
2. Put 1ml of alcohol into test tubes 1 and 2.
3. Add 1 drop of vegetable oil to the alcohol and shake from side to side until the oil is dissolved into the alcohol.
4. Add 2ml of water to test tube 3 and 4.
5. Pour content of 1 into 3.
6. Pour content of 2 into 4.

Results:

1. Complete the table below:

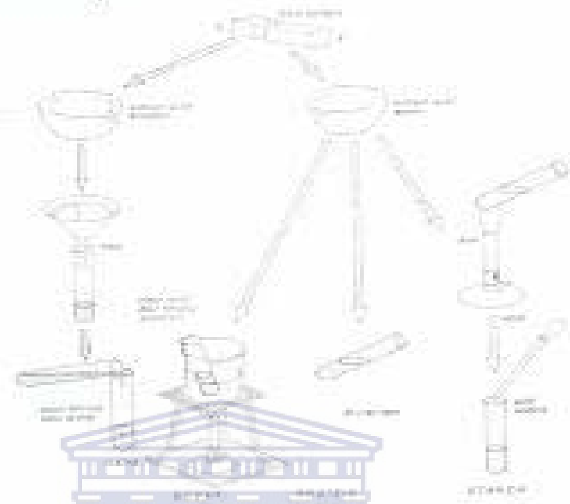
Tube	Contents	Appearance when water is added
3	Alcohol and oil	
4	alcohol	

2. What was the only difference between the contents of test tube 1 and 2?
3. What difference could you see between test tube 3 and 4 after adding the contents of 1 and 2?
4. What do you think caused the liquid in test tube 3 to react like it did?

APPENDIX J

Practical 2.4

General tests for food samples



Complete a table for each food substance you have tested. Do at least one type of food from every food substance.

Food sample:		
Test	Result	Interpretation
Emulsion test		
Benedict's solution		
Biuret test		
Iodine test		

Food sample:		
Test	Result	Interpretation
Emulsion test		
Benedict's solution		
Biuret test		
Iodine test		

APPENDIX K

Test for Starch

Aim - To see weather food substances contain starch.

Equipment - Pestle
- Mortar
- Blotting tile
- Iodine solution - yellow brown colour
- Spoon

Method -

2. Starch	Iodine solution, a yellow-brown colour	Add iodine solution directly to the food, or to a solution of it. If a blue-black colour appears, starch is present

Results -

Reagent added	Onion	Potato	Peanuts	Orange
Iodine	x	✓	x	x

√ (4)

Conclusion - The solution only turned blue-black in the potatos because only they contain strach.

Questions:

1a. The reagent turns blue-black
b). The reagent stays yellow brown

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2. Carbohydrats make up the cell ~~wall~~ and plant cells.

1. How do you know when starch is

(a) present in a food substance? [1]

(b) not present in a food substance? [1]

2. Why is a carbohydrate stored in the form of starch in plants? [2]

APPENDIX L

Test for fats and oils

Aim - To test weather food substance contain fats and oils if tested in Ethanol.

Equipment - Spoon
- Mortar
- Water
- Ethanol
- Beakers

Method -

4. Fats and oils	Ethanol: emulsification test	Shake the food to be tested with ethanol. Then pour off the ethanol into some cold water. If fat is present the water-ethanol mixture will turn a cloudy white due to the formation of an emulsion

Result -

Reagent added	Onion	Potato	Peanuts	Orange
Ethanol	x	✓	✓	x

X ✓ (4)

Conclusion - The solution turned cloudy white only in the potatos and peanut because the contain starch.

8/11

A'p

Questions

1. When the reagent turns cloudy white

1. How do you know when fat is present in a food substance? [1] cater
2. Why is ethanol used? [2] in tiny globutes
3. What is an emulsion? [1]
4. What happens during emulsification? [2] of ethanol

APPENDIX M

Test for reducing sugar.

Aim - To test which food substance contains reducing sugar.

Equipment - Morter
- Spoon
- Pestle
- Gas burner
- Matches
- Benedict solution

Test tube rack
Test tubes
Tit pepet

Method -

Chemical compound	Test reagent	Method of identification
1. Reducing sugars, such as glucose, maltose	Benedict's solution contains copper sulphate, a blue solution	Heat a solution of the substance to be tested with Benedict's solution. A positive result, indicating that a reducing sugar is present, is a change from a blue solution to a coloured precipitate. The colour of the precipitate will vary depending on the amount of sugar: A greeny-yellow colour means a small amount of sugar is present; orangey-red colour means a large amount of sugar is present

Result -

Reagent added	Onion	Potato	Peanuts	Orange
Benedict Solution	✓	✗	✗	✓

Conclution -

1. How do you know when

   (a) a small amount of sugar is present in a food substance? [1]

   (b) a large amount of sugar is present in a food substance? [1]

2. What chemical gives a blue colour to the Benedict's solution? [1] coloured persepitate

3. What is meant by a reducing sugar? [1]

4. With which element in copper sulphate does the reducing sugar react? [1]

APPENDIX N

Test for Vitamin C DCPIP = 2,6 Dichlorophenol-Indophenol-Sodium

Aim → To see if Vitamin C is present in food substance

Equipment - Mortar DCPIP
Pestle
Syringes
Surgical gloves
Test tube
Test tube rack

Method -

1. Draw up 2 cm³ of DCPIP into a plastic syringe.
2. Release this into a test tube.
3. Draw up 2 cm³ of the food substance solution into another plastic syringe.
4. Add this drop by drop into the test tube containing the DCPIP.
5. Repeat steps 3 - 4 several times and record the amount added.
6. If the DCPIP becomes colourless than Vitamin C is present.
7. The more food substance solution it takes to decolourize the DCPIP, the less vitamin C it contains.

Results -

Reagent added	Onion	Amount added	Potato	Amount added	Peanuts	Amount added	Orange	Amount added
DCPIP	X	6ml	X	6ml	✓	6ml	✓	2ml

Conclusion - There is only Vitamin C present in the orange and the peanuts.

Questions

7/10

1. How do you know when vitamin C is present in a food substance? [1]
2. Why should you not use heat for this practical? [2]
3. Why is it important that the amount of food substance added should be recorded? [2] unt of vitamin C

APPENDIX O

Test for Proteins

Aim - To see if food substance contain proteins

Equipment - Test tubes — Sodium Hydroxcide
Test tube rack — Copper Sulphate
Mortar
Spoon
Pestle
Beackers

Method -

3. Proteins	Biuret test reagents: sodium hydroxide; 1% copper sulphate solution, a blue colour	Add a little sodium hydroxide to a solution of the food to be tested. Then add 1% copper sulphate solution drop by drop. If the solution turns purple, protein is present

Results -

Reagent added	Onion	Potato	Peanuts	Orange
Sodium Hydroxide + Copper Sulphate	X	X	✓	X

✓(5)

Concultion - From all the tests dun it is only peanut that contain protiens

Questions -

1. How do you know when protein is present in a food substance? [1]
2. What are the reagents? [2]
3. Why should you not use heat for this practical? [2]

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3. Because they produce there own heat

Appendix P
VOQS: Categories of teacher-learner interactions

Teacher's Activities Category		Descriptors of activities
Teacher actions in the flow of discourse		
1	Practical skills	73. Manipulates materials/ apparatus 74. Makes measurements 75. Reads instructions 76. Follows instructions
2	Carry out demonstration	77. Uses real specimen/materials 78. Prepares solutions just before starting with demonstration 79. Carries out the activity
3	Provides assistance to learners	80. To carry out an activity 81. To take measurements 82. To carry out an activity in a small group
Forms of utterances		
4	Describes what to be observed	83. Event, phenomena 84. Patterns 85. Remarks about what should be observed 86. Content, apparatus and materials used
5	Explanation provided	87. About an event, phenomena 88. About the procedures to be followed in completing a task 89. About a procedure in taking measurements
6	Opportunity provided to	90. Make and record observations 91. Complete a table 92. Make and record measurements/estimates 93. Discuss results/ anomalous results
Nature of teacher interventions		
7	Shares ideas	94. Science content or procedural information 95. Repeat an idea 96. Share group/learner's findings 97. Asks learners to prepare or complete a table, a graph 98. Reminds learners about safety precautions, format to write report
8	Selecting ideas	99. Work on ideas 100. Developing the scientific story
9	Shaping ideas	101. working on ideas 102. developing a story
10	Marking key ideas	103. working on ideas 104. developing a story
11	Checking learner understanding	105. probing for meanings 106. probing a specific group for meanings 107. checking on continuity
12	Reviewing	108. returning to and going over ideas

- I - stands for initiation: normally through questions from the teacher but learner may also pose questions.
- R - stands for response: from the learner or teacher
- E - stands for evaluation: by the teacher
- F- stands for feedback (could be elaborative feedback).

Appendix Q

VOQS: Learner-learner interaction in an experimental group

The learner-learner actions in the flow of discourse in group experiments involve the patterns of interactions, the focus of the learners' discussions and the types of explorations.

Learner-learner interaction	
Patterns of interactions	verbal and non-verbal (actions)
Focus of discussion	Procedural
	Resources
	observation
	Interpretation of results
Types of exploration	questioning ideas
	explaining ideas
	criticising ideas
	offering an idea/answer
	reinforcing responses