EFFECTS OF EXEMPLARY TEACHING AND LEARNING MATERIALS ON STUDENTS' PERFORMANCE IN BIOLOGY

by

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Dedication

To my three 'reasons for being'; my darling wife Hannah and our two precious gifts from God; Khumoyame and Aobakwe.

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[1]Song of Solomon, 2:2; [2]Proverbs, 31:29.

DECLARATION.

I declare that **Effects of Exemplary Teaching and Learning Materials on Students' Performance in Biology** is my own work and that all sources I have used or quoted have been indicated and acknowledged by means of complete reference.

Gaobolelelwe Jimmy Ramorogo.

Table of contents

List of tables

List of figures

ABSTRACT.

This study sought to determine the effects of exemplary teaching and learning materials on students' participation and achievement in biology in Botswana science classrooms. In particular, it was concerned with examining the effects of student-teacher-material interactions on the students' participation and achievement in biology. The method adopted for this study was an eclectic approach in which both quantitative and qualitative approaches were used to complement each other. In order to understand the social processes and meaning that the participants in this study attach to phenomena, a qualitative approach based on social interactionism was adopted.

The role played by the researcher in this study was that of a participant-as-observer. To explore life in Botswana biology classrooms and to unravel the complex social aspects of teaching and learning, a holistic ethnography (used alongside a variety of micro-ethnographies) were adopted for the study.

Ten experienced biology teachers were involved in identifying the topic that could be developed for exemplary practice as well as in validating the materials that were produced. They also responded to the exploratory questionnaire on the traits of an exemplary biology teacher, which formed the basis for the development of the exemplary package.

An induction workshop was conducted for the exemplary teachers to help them explore and reflect on their practice with a view to create in them an appreciation for the exemplary approach to teaching and learning. The curriculum package consisted of the students' workbook, scheme of work, lesson plans and an achievement test.

A sample of seven schools was used in the study. Two schools were used for each of the co-operative, competitive and individualistic groups and the last school was the used as the true control group. To minimise the effects of contamination, the treatment groups were chosen from different areas of the country. A total of seven teachers and 446 students were involved in the study. A quasi-experimental research design modified from the Solomon-three-control group design was used. Also, qualitative methods were used to capture the data that were not easily amenable to quantification.

The findings of this study suggest differences in the interaction behaviours of conventional and exemplary teachers. The conventional teachers tend to out-talk their students while the exemplary students tend to out-talk their teachers. Also, the verbal and non-verbal interactions of the conventional teachers exceed those of their students. On the other hand, the students' verbal and non-verbal interactions exceed those of the teachers in the exemplary classes. Teachers in both the exemplary and conventional classes ask predominately factual questions compared to the exemplary teachers who ask more leading and probing questions.

Students in two treatment groups (co-operative and competitive experimental) performed significantly better than those in the true control group. However, performance in the two treatment groups with respect to achievement in the Biology Achievement Test is quite identical. No significant difference is observed between the performance of the students in the third treatment group (individualistic) and those in the true control group.

The use of exemplary teaching and learning materials seemed to have enhanced the achievement of the girls, low ability and average ability students in all the assesed variables while the conventional teaching strategies seemed to have enhanced only the achievement of the average ability students.

Students perceive an exemplary teacher as the one who; (i) encourages student participation irrespective of their gender and academic ability, (ii) gives homework and marks it, (iii) ensures that students are on task.

Students in exemplary classes describe their experiences in practical activities as enjoyable, providing opportunities to learn new things and providing specific episodes during bilogy lessons.

When the learning task is unfamiliar, students seem to ask more procedural questions in their small groups, while they tend to ask more thought-provoking questions if the learning task is familiar.

In group discussions, students seem to use a variety of strategies to improve the chances that the group accepts their ideas. These include among others, discrediting the source of the counter-argument, sarcasm, substantiating their arguments, lobbying for support and introducing new evidence.

CHAPTER ONE.

1.0.0 Introduction

1.0.1 Background to the study.

The curriculum innovations of the 1950's which started in the United States and Europe rapidly spread throughout the world and greatly changed the way science was to be taught (Okatch, 1980; Jenkins, 1994; Ogunniyi, 1995). At the international scene, funds were made available to develop courses that would allow students to work "like practising scientists". The new courses were to be based upon an inductive problem-solving philosophy (Jenkins, 1994) and the development of process skills. Inherent in these new curriculum models, was the emphasis on the child as an active participant in the learning process and on the inquiry modes of knowledge acquisition (Schwab and Brandwein, 1966; Jansen, 1989). An important feature of inquiry is to allow pupils to interact with the learning environment and perhaps this is one of the reasons why practical work has become a unique feature of science education today.

Just as scientists need laboratories to carry out their investigations, school science have come to be associated with special rooms that provide ample opportunities for students to carry out experiments. The school science laboratory provides an environment where students can test how valid their intuitions, hunches and ideas are with respect to the scientific viewpoints. According to Schwab and Brandwein (1966) school science before the 1950's was more or less a "rhetoric of conclusions" to be committed to memory or a body of knowledge to be verified in contrived laboratory experiments (Solomon, 1991; White, 1991; Roth, 1993).

Africa was quite susceptible to these exogenous curriculum models of the 1950's and the 1960's for several reasons. Of particular interest to this study was the faith that was placed on science and technology as the primary means to socio - economic growth especially in a setting lacking the indigenous frameworks with which relevant and appropriate science courses could be developed (Jansen, 1989). In that context the new curriculum packages became something the newly independent African states could hardly resist (Okatch, 1980; Jenkins, 1994). Of course, in view of capitalist interest, the former colonial powers saw investment in science by African states as a potential extension of their market.

It is apposite to clarify the term "inquiry" as used in relation to science teaching and learning as the extant literature does reveal more than one interpretation. For instance, Fish and Goldmark (1969) identified three types of inquiry. First, is the self directed module: a situation where the learner is allowed to direct and control his own learning. The teacher is seen as a facilitator of learning and is expected to provide a climate and conditions that would encourage the learner to progress in the inquiry. The teacher would also assist the learner to evaluate his progress and also provide the assistance the learner needs to achieve his objectives. Second, in inquiry into science teaching which involves a systematic analysis and evaluation of one's teaching behaviour in an attempt to reflect on the consequences of such behaviour on the learners. Third, is inquiry teaching as a method selection. This approach focuses on the decisions that the students make about which method to use in their science inquiry. In this case the learners make decisions about which method to use, experience the consequences of using that method and assess the consequences of the discrepancies they could be encountering.

Schwab (1969) also distinguishes between fluid and stable inquiry. According to Schwab, stable inquiry arises when the researchers regard conceptual principles supplied by others as a matter of fact. The status of the principles is taken as absolute and they are used as a means of enquiry and not questionable entities to be enquired into. In fluid inquiry, the main aim of the researcher is to establish the validity and reliability of the principles as research tools. The researcher is interested in the limitations of such principles as cognitive tools in advancing research in the stable inquiry.

The emphasis on inquiry stems from at least two needs: (i) enlargement of the scientific/ technological human power to encounter the challenges posed by the Sputnik (1957) and (ii) the change in the epistemology of Science itself from being a "rhetoric of conclusions" to a dubitable, revisionary human enterprise (Schwab and Brandwein, 1966; Kuhn, 1970).

Roth (1993) sees a science laboratory as a construction site. Inquiry from a constructivist perspective expects students to work more independently, choosing their own paths of investigation, determining their own research agendas and setting up and conducting their experiments to make discoveries for themselves in the laboratory. The students in this situation are not provided with 'cookbook recipes' for the experiment but rather are afforded a chance to discuss the meaning of the problem in question and the appropriate experimental design for it. In this case, different groups could possibly decide on different designs and of course, may get the same or even different results for the same problem. As the students reflect on their experimental designs, procedures and results collaboratively, they are actively involved in the process of constructing knowledge. From a social constructivist perspective, learning in collaborative groups is viewed to facilitate and accelerate the construction of new conceptual and procedural knowledge (Roth, 1993). A collaborative learning environment has cognitive benefits in that it provides for a discourse situation in which meaning could be negotiated in the process of solving a problem. It is this form of inquiry that this study embraces and adapts for Botswana conditions where the curriculum is overloaded and the national examinations overhang the curriculum.

1.1 Science as an inquiry.

For many decades now, science has been taught "as an inquiry". Schools have built laboratories as places where students learn their science by doing things. Practical work forms an important part of inquiry learning. It is assumed to provide concrete props to help pupils comprehend the complex and abstract concepts of science (Tamir, 1991). Practical work is used to clarify concepts, elucidate theory, illustrate phenomena, verify facts and principles and confirm theory. Kerr (1963) cited a chemist as asserting that, "learning chemistry without practical work is like learning to swim without water - merely impossible." According to Solomon (1980), it is by doing experiments and creating concepts at first hand in the laboratory that this understanding of science was to be achieved. It is also believed to have a salutary effect on the development of scientific skills among pupils. Of course, practical work has various interpretations since any learning method that requires the learner to be actively involved in the learning situation presupposes the belief that children learn best by direct experience (Hodson, 1988).

Practical work has a great potential to make phenomena real to the pupils. This is what Woolnough and Allsop (1985) refer to as getting the "feel" for the phenomena or what Hodson (1992) believes constitutes an important aspect of personalising science. Others claim that practical work serves as (i) an aid to conserve memory (Solomon, 1980; White, 1991); (ii) an opportunity to discuss things in science; (iii) a conceptual model for evaluating levels of understanding (Barnes, 1976); (iv) a tool for conceptual change as well as a means to explore, unravel and identify misconceptions (Solomon, 1991; Aho, Huopio and Huttunen, 1993; Wenham, 1993; Ramorogo, 1994; Ramorogo and Wood-Robinson, 1995).

In the recent past, the processes of science have been considered very important components of most science curricula. Some curricula were even developed based on the processes of science (Hodson, 1991). Process skills are assumed to be critical elements of scientific inquiry as they offer ample opportunities for students to make accurate observations, measurements, use scientific apparatus correctly, acquire and use standard techniques, read, understand and carry out instructions, record data and communicate their results with other people (Van Praagh, 1983; Solomon, 1991; Tamir, 1991; White, 1979,1991).

Critics of practical work, however, argue that using it to meet didactic aims is a very expensive way of teaching science (Woolnough and Allsop, 1985). It has been observed that most of the practical work is done as a matter of ritual and tends to become a mere confirmation of "rhetoric of conclusions" (Schwab, 1962; Schwab and Brandwein, 1966; White, 1979; Woolnough and Allsop, 1985; Solomon, 1991). Also, there is sufficient evidence to suggest that practical work fails to fulfil the purposes for which it is set up and as such, becomes an unproductive exercise (Driver and Millar, 1978; White, 1979; Solomon, 1980; Hofstein and Lunetta, 1982; Driver, 1983; Hodson, 1988). As a result, a reflective approach to learning and teaching could prove to be helpful in that practical work would cease to be regarded as a panacea to conceptual problems but rather as a pedagogical tool which could be used only if it is necessary and when it yields worthwhile cognitive benefits.

1.2 Conditions for teaching and learning science.

For nearly two decades now, especially since the first National Commission of Education in 1977, science has been made a compulsory subject in the school curriculum. There is also some evidence to show that the conditions of teaching and learning science have improved significantly within the period (Kann and Nganunu, 1992; Marope, 1992; Ogunniyi, 1995). Ogunniyi (1977) identifies the conditions under which science is taught as an important factor that could enhance or hamper the full achievement of the reward structures in science education. A review of research findings indicates that a considerable number of Botswana secondary schools have well equipped science laboratories and well trained science teachers though most of them are expatriates (Pendaeli, Ogunniyi and Mosothwane, 1993). This however, is not the same as saying that the teachers are adequate in number or are performing to expectation. In fact, the instructional styles of many a science teacher in Botswana leaves much to be desired. Perhaps, this explains why a considerable percentage of the students are under-achieving in science (Republic of Botswana, 1991; Kann and Nganunu, 1992; Motang, 1992; Ngueja, 1992; Pendaeli et.al., 1993; Prophet and Rowell, 1993; Ogunniyi, 1995).

There is a general feeling in Botswana that the products of the education system in general lack scientific knowledge, and tend to recede into scientific illiteracy (Kahn, 1990). It is also observed that even though the number of students enrolling in senior secondary schools is increasing, the same increase is not reflected in the performance of students. There seems to be a gradual decline in performance (Pendaeli, Ogunniyi, and Mosothwane, 1993). This decline can be explained in a number of ways. One of the reasons is related to the teaching strategies used by the teachers. Too often, teachers resort to chalk and talk, drill and practice and closed question and answer methods which place a lot of emphasis on memorisation of information instead of providing children with opportunities to construct their knowledge (Prophet, 1990; Prophet and Rowell 1990; Rammiki, 1991; Fuller and Snyder, 1991; Ogunniyi and

Ramorogo, 1994). Other reasons are not unrelated to the neglect of: (i) the effects of the pupils socio-cultural environment; (ii) the ideas pupils bring to the learning situation and (iii) the mismatch between instructional tasks and the ability levels of the students (Hilsdon, 1993; Prophet, 1990, 1995; Ogunniyi, 1995). There is also a growing concern that despite the tremendous growth in school enrolment, not much has been achieved in terms of quality (Republic of Botswana, 1993; Youngman, 1993). This is a serious concern particularly when it is viewed against a background of gradually declining economies of the developing countries including Botswana. Hence, research into what teachers are doing in school science classrooms, their professional background and their epistemological frameworks might provide some clues to the nature of their interaction behaviours.

1.3 Classroom or laboratory interactions.

According to Novak (1990) teaching does not necessarily result in learning. At its best, teaching probably helps the learner to organise his/her experience in such a way that it will promote meaningful learning. It is through interactions with the teachers, other students and learning materials that students construct meanings of the world around them (Driver, 1989; Ramorogo, 1992). However, not all classroom interactions contribute to the construction of scientific meaning (Shepardson, Moje, and Kennard-McClelland, 1994). Only those that resolve the disparity between the learner's cognitive structure and scientific knowledge tend to facilitate the construction of new meanings from pre-existing ideas (Vygotsky, 1986; Driver, 1989;

Millar, 1989; Hewson and Thorley, 1989; Ramorogo, 1994; Ramorogo and Wood-Robinson, 1995).

Cultural studies suggest that the students' worldview presuppositions have a significant impact on their interpretation of concepts and ideas in science (e.g. Ogawa, 1986;1989; Ogunniyi, 1986; 1987;1988; Jegede and Okebukola, 1989;1990; 1993; Cobern, 1993;1996; Aikenhead, 1996; Ogunniyi, et.al., 1995; Fedock, et.al.,1996). As such, the success of the teaching and learning process depends to a great extent on an understanding of the learners' socio-cultural environment (Cobern, 1993). In other words, for successful teaching and learning to occur, the idiosyncracy of the learner's culture should be taken into account (Haidar, 1997). While issues of culture are important in the teaching and learning process, the specific focus of this study and space limitation will not permit a detailed account of the cultural elements. Rather, the emphasis would be the classroom social environment. Future work would certainly take advantage of the excellent materials emerging from cultural studies in the field of science education.

The construction of knowledge does not take place in a social vacuum. It involves sharing and negotiating meanings with others in the classroom (Barnes, 1976; Driver, 1989; Cobb, 1990). Students in this sense are social beings and stimulus seekers (McCaslin and Good, 1992). As a result, a pedagogy that seeks to achieve such construction of knowledge need not only afford the pupils opportunities to do laboratory work, but also to engage them in a process of actively thinking about how their investigations relate to the ideas they are developing (Driver, Squires, Rushworth and Wood-Robinson, 1994). In so doing, they are developing personal ownership and appreciation of the acquired knowledge (Brophy and Alleman, 1991).

In a way, experience should not be an end in itself. The sense pupils make of an experience is critically important to their overall behaviour (Driver, Squires, Rushworth and Wood-Robinson, 1994). As alluded to earlier, neither the availability of well-equipped laboratories nor the exposure of learners to experienced teachers guarantees successful learning. For one thing, the length of years of experience does not automatically predispose expertise (Reynolds, 1992), neither does a teacher's qualification imply effective communication of subject matter. Effective teachers tend to: (i) have an intuitive grasp of the situation; (ii) be able to sense in non-analytic and non-deliberate ways the appropriate response to be made, and (iii) show fluid performance rather than consciously choosing what or not to attend in a given instructional setting (Berliner, 1994). These eclectic, interactive skills are important referents of exemplary practice because they distinguish an effective teacher from an efficient one. An efficient teacher is not necessarily effective. An efficient teacher would cover the work that needs to be done in a given time. This however, does not necessarily mean that he/she would achieve results in terms of students' cognitive gains and other intended goals of the lesson. An effective teacher on the other hand would achieve recognisable results from the work done (Dyer, 1983; Ogunniyi and Ramorogo, 1994). As such, effectiveness at best, could be considered against one's own goals of teaching (Brown and Atkins, 1987). Consequently, while both efficiency and effectiveness are desirable in a teaching - learning situation, effectiveness is a more preferable goal.

Two critical variables have been identified in the teaching-learning process. These are: content area knowledge - a good grasp of what is to be taught and pedagogical knowledge - knowing how to deliver knowledge such that it can be learnt (Shulman, 1986, 1987; Reynolds, 1992; Preece, 1994). Research evidence seems to suggest that the classroom discourse and the teaching strategies vary as a function of the teacher's mastery of the subject matter knowledge. Teachers with a good mastery of content tend to: (i) allow students ample opportunities to ask questions; (ii) appropriately target their questions by asking questions that are appropriate for the level of students' cognitive development and their level of achievement; (iii) engage students in those activities that are more likely to enhance learning- including open ended discussions (Fraser and Tobin, 1990; Carlsen, 1993; Lee, 1995). This may suggest that teachers' knowledge of the subject invariably influences the instructional strategies students are exposed to (Reynolds, 1992; Carlsen, 1993; Gess-Newsome and Lederman, 1995). In other words, teachers with a good grasp of the content can freely vary the teaching strategies to enhance opportunities for students to meaningfully interact with the learning materials (Tobin and Fraser, 1990; Carlsen, 1993). Good subject mastery therefore, seems to be a necessary though not the sole desideratum of exemplary practice. It is the delicate balance between these, the reward structures used, the context, the process and the product variables of instruction that constitute exemplary teaching (Shulman, 1986; Kyriacou, 1986, Sherman, 1988).

1.4 Exemplary practice.

Exemplary teaching encompasses not only the knowledge of the content matter and the pedagogical strategies, but also the intuitive grasp of the classroom situation such that responses to incipient problems are made effortlessly and flexibly (Kyriacou, 1986; Berliner, 1994; Farrell, 1994; Ogunniyi and Ramorogo, 1994; Zahorik, 1994). Presumably, such cognitive gains and competence evolve over time from training, practice, drive and creativity on the part of a teacher (Farrell, 1994).

Cuban (1992) makes a distinction between problems and dilemmas in instructional settings. In a problem situation, a constraint exists, that impedes the achievement of a desired goal. To solve this problem though, does not necessarily require any compromises. In a dilemma situation, however, solving a problem involves some opportunity cost. For instance, something that is considered equally important may be set aside either because its inclusion will require additional time and materials or because it is not critical at that point in time. According to Tripp (1993) teachers use good techniques and routines, but these alone cannot produce good teaching. It takes expert judgement in circumstances where there are no clear-cut solutions to achieve this. It is perhaps the dilemmas and the choices made thereof, more than the problems that make life in the classroom markedly different. This is particularly crucial to avoid making choices that may lead to poor attainment of goals or undesirable consequences.

According to Brickhouse and Bodner (1992) teaching is a context-based activity. The contexts are sometimes clear but more often they are rather murky and intractable (Leinhardt, 1990). Teaching is thronged with dilemmas and problems peculiar to each setting (Tippins, Tobin and Hook, 1993). Research evidence reflects teaching as a complex, context specific, interactive activity (Cochran-Smith and Lytle, 1990). It requires moment by moment adjustments of plans to suit continuously changing and uncertain classroom environments (Lampert and Clark, 1990). According to Kagan (1990) and also (Bryk, 1988) skillful classroom instruction is not only an aesthetic experience but also an "intensely personal activity". This in part constitutes the differences between the quality of instruction across classrooms. Hence, a teacher's ability to create a classroom environment, which fosters meaningful learning, is not only a science, it is also an art.

The classroom environment has powerful effects on educational outcomes (Wiseman, 1973; Ogunniyi, 1995;1996) and yet, in a developing country like Botswana, the craft of establishing and maintaining a conducive classroom environment without being an authority figure (Brophy, 1987) seems to be a private affair (Wragg, 1994) in that such teachers never document it and share it with others. As pointed out earlier, pupils are social beings. The societies they come from seem to condition them into certain behavioural and interactional patterns. Apart from bringing into the learning environment their worldview presuppositions (Jegede and Okebukola, 1990; 1993; 1995; Ramorogo, 1992; Cohen, 1993; Ogunniyi and Yandila, 1994; Ogunniyi, et. al., 1995; Ramorogo and Wood-Robinson, 1995; Cobern, 1996; Fadock, et.al., 1996), pupils also bring along a process of socialisation that reflects their "culture" (Horton, 1971; Solomon, 1987; Ogunniyi, 1988,1989; Fensham, 1988; Driver, 1989). One's culture 'controls perception and sets attitudes and beliefs about objects, events, or situations' (Hoebel, 1965. cited in Ogunniyi, 1989). According to Thaman (1993) culture informs the unique way in which different cultural groups perceive and organise their world. In this sense, it is central to the understanding of the interactions between members of the group. The variables associated with the way an individual interacts with the environment on the one hand and shares certain interaction patterns with members of the community on the other, tend to have an effect on the learning process (Ehindero, 1982; Okebukola, 1986; Welch, 1993; Ramorogo, et. al. 1994). This study views learning as a form of socialisation in which the learner is initiated into the values, norms, ethics, concepts, methods and language of science by the members of the scientific community.

1.4.1 Students' gender and exemplary practice.

Despite concerted efforts to open equal access for boys and girls into schools, there continues to be large differences in the performance of boys and girls in science achievement (Meece and Jones, 1996). While this gender gap seems to be closing in mathematics as a result of a long period of intervention, it appears to be widening in science achievement (Kahle and Meece, 1994). A review of research studies seems to suggest that the youngest pupils in primary schools seem to show no gender differences in their performance in science (Shaw and Doan, 1990; Solomon, 1997). Also, that the differences in participation and achievement between boys and girls increase from the middle grades to post-secondary levels (Kahle and Meece, 1994; Catsambis, 1995; Meece and Jones, 1996).

In order to address this gender gap and under representation of females in science disciplines, research focussed on a variety of issues. Earlier studies concentrated on the biological differences between boys and girls. For instance, the genetic deficits such as the small skull, or inherent lack of spatial ability in girls (Solomon, 1997). As Haggery (1995) points out, such studies seem to suggest that females are somehow deficient and that their participation and achievement would increase if they could be made more like men and hence more suited for science. Linn and Hyde, (1989) however, argue that differential ability based on such biological differences is a myth.

Gender differences in the learning strategies exhibited by the two sexes have also been a focus of study in order to explain the differences in the participation and achievement of boys and girls in science. Several studies seem to suggest some profound differences their modes of social collaboration, discourse styles and preferred ways of thinking. Evidence from studies on classroom interactions seems to suggest that girls collaborate more effectively than do boys (Solomon, 1997). As a result, girls may be expected to do better in co-operative learning settings and in situations where discussions form a major part of the learning process. Perhaps, this explains why girls do not perform so well in multiple choice questions (Meece and Jones, 1996; Hazel, Logan and Gallagher, 1997). Boys, however, tend to employ competitive verbal interactions, strive for dominance and be more interested in emerging a winner (Spender, 1980; Alexopoulou and Driver, 1997).

Research evidence also seems to suggest gender differences in the discourse styles of boys and girls. For instance, in small group discussions, male and female students appear to differ in the ways they raise their objections and negotiate their ideas. Alexopoulou and Driver (1997) assert that female physics students tend to negotiate their ideas more tentatively and in the process raise their objections indirectly in the form of questions. Males, however, seem to raise their questions more directly.

There is also a strand of research which suggests that science does not appeal to the female students' way of thinking. Such studies tend to interpret the under-achievement of female students in science in terms of the culture of science. According to Kelly (1985), men have essentially constructed science and as such it embodies an intrinsically masculine worldview. The essence of this is that science tends to be socially accepted as a male domain. As such, when the boys participate and excel in science activities, it is viewed as an acceptable way of reinforcing their masculinity while the same cannot be said about girls (Sjoberg and Imsen, 1988; Haggerty, 1995). Thus, instead of asking what it is about girls that needs to change in order for them improve their performance in science, perhaps the question should be what is it about science that makes it less appealing to them that needs to be changed. The argument here is that the teaching-learning activities and practices in science may only be rewarding the masculine ways of knowing and knowledge. According to

Hazel, Logan and Gallagher (1997) masculine ways of knowing place emphasis on competition, dichotomous thinking and learning in the abstract while the feminine forms of knowing and learning are characterised by emphasis on co-operation, learning in context and holistic thinking. Thus in order to make science more appealing to girls, and hence, accessible to all, it should be approached from a holistic perspective. The context of what is taught should also be kept close to what is personal in everyday life (Sjoberg and Imsen, 1988; Haggarty, 1997; Solomon, 1997). If the participation and achievement of girls in biology in considered an important aspect of teaching and learning, then, the relevance of a gender balanced approach in exemplary practice cannot be over-emphasised.

1.5 The place of reflection in exemplary practice.

It is now becoming fashionable to talk about reflective practice in teaching and learning situations. However, it is not always clear what is meant by the term. Reflection, in the Webster's Third New International Dictionary of the English Language Unabridged, is defined as "...consideration of some subject matter, idea, or purpose often with a view to understand or accept it or seeing it in its right relations..." p.1908. Dewey (1933) perceives reflection as a particular form of thinking. It starts when one experiences a situation in which she/he is perplexed and results in purposeful inquiry and a tentative resolution of the problem (Grimmet, 1988; Laboskey, 1994).

The word reflection has been used to mean different things at different times and the definitions are not used consistently by theoreticians, researchers and teacher educators (Laboskey, 1994). For the purpose of this study it is apposite to clarify the term as much as possible.

Hullfish and Smith (1969:36) define reflection as a one form of thinking that "differs from the looser kinds of thinking primarily by virtue of being directed or controlled by purpose - the solution to a problem". Reflection immediately purports to resolve a problem and in the long run, growth of the individual and the classroom culture (Laboskey, 1994). Reflection always leads to a consequence; it involves conceptualising perplexity as a problem to be solved, and the possible courses of action to solve the problem are entertained as hypotheses to be tested first by mental elaboration and by experimental corroboration of the conjectured ideas (Grimmet, 1991).

Analysis of research on reflection in education suggests different conceptions of reflection based on the ontological perspective on which research-derived knowledge is seen to contribute to teacher education. Grimmet (1991) suggests three categories of such reflections.

In the first category, reflection is portrayed as being thoughtful about what one is doing. This thoughtfulness should result in a deliberate and active application of research findings, for example, to the teaching situation. Proponents of this view tend to hold a technical and mechanistic perspective of teaching. In this view, "new information" that could be used to direct practice come from "authorities" - those who have done research and published their findings in journals and not from the classroom situation itself (Grimmet, 1991).

The second category posits a pragmatic and eclectic view of reflection as a consideration and choice among possible versions of "good teaching". Attention is here paid to the context in which educational events occur. Each teaching strategy is examined in terms of the worth of each interactional behaviour to the teaching-learning exercise. (Grimmet, 1991). Of great importance here is how the consequences of such interactions would benefit the students. Hence reflection is seen as a means to inform practice.

The third category of literature on reflection draws explicitly from a constructivist view of knowledge (Grimmet, 1991). Reflection is portrayed as a means of appreciating and enhancing practice. Consequently, it is viewed as the reconstruction of experience in the sense that situations that were previously taken for granted or ignored are made problematic and assigned new significance as a result of a change in the way the underlying assumptions are perceived (Grimmet, 1991). In the words of Russel and Munby (1989), such situations are "seen" and "heard" differently as the teacher starts to reconsider a range of alternative responses to the problem. Also, interpretive accounts, derived from hermeneutic studies of what teachers do in their classrooms (in terms of how they structure their knowledge and how they exploit such knowledge within the context of the cultural milieu within which they teach) provide a new perception of the self as a teacher. Reflection therefore, provides an opportunity for teachers to structure and re-structure their personal, practical knowledge (Grimmet, 1991; Clarke, 1994). Furthermore, reflection can be seen as re-construction of taken for granted assumptions about teaching. It involves the means-ends analysis of the problem situation. For this reason, it is important to consider to what ends and in whose interest is the knowledge being used (Schön, 1983; Grimmet, 1991). This process of sense making about one's experiences in the classroom models an inquiring approach central to reflective practice (Richert, 1991).

Despite varied viewpoints about the term, there is a general consensus that reflective teaching is a crucial though not sufficient condition of exemplary practice. More importantly, teaching and learning are known to be dynamic and complex processes occurring in a social milieu in which the needs of the students may vary from one context to another. Furthermore, these needs and inherent problems are neither easily detected nor definitively interpretable (Laboskey, 1994). As Richert (1991) suggests, the process of reflective teaching is "intellectual rather than routine, expansive rather than singularly focused". Given the situational nature of teaching, the teacher makes sense of his/her experiences as he/she interacts with the teaching situation and in the process models an inquiring approach that will enable him/her to put his/her creative insight and novel ideas into action - a process central to reflective practice (Goodman, 1991; Richert, 1991).

As pointed out earlier, this study assumed a social constructivist approach to explore exemplary practice in biology classrooms in Botswana. For this reason, the third category of literature on reflection was considered to hold promise for this study. This category embraces Schön's notion of reflective teaching, which entails an orientation to inform and apprehend practice, and is constructivist in nature. According to Schön (1988:19), reflective teaching involves

> "giving the kids reason": listening to kids and responding to them, inventing and testing responses likely to help them get over their particular difficulties in understanding something, helping them build on what they already know, helping them to discover what they already know but cannot say, helping them co-ordinate their own spontaneous knowing-in-action with the privileged knowledge of the school.

This conception of reflection is important in that it pays particular importance to the learner. In this process, both the teacher and the pupil are involved in a process of inquiry, the aim of which is to share the meanings of the phenomena in question. One particular strength of this conception of reflective practice is the ease with which it can be adopted for teacher training. The assumption here is that one can train reflective teachers in the context of doing. Perhaps, this could be achieved through providing teachers with a "Hall of Mirrors": a situation in which reflective teaching is demonstrated in the very process of trying to help someone to learn it (Schön, 1983; 1989;1991).

Since problems in teaching and learning situations are in no way uniform, situations of perplexity are just as varied. In this sense, pre-defined strategies and ideas may not be appropriate and adequate in meeting the needs of the students and resolving incipient problems. This developmental perspective of reflection impels one to inquire (Gore, 1987; Grimmet, 1988). This goes beyond just responding to variations of routine problems in the classroom. It involves responding to a surprising situation in which both the context and the response go beyond the familiar (Schön, 1983). This suggests that the teacher should be able and ready to venture into an authentic conversation with the problematic situation. This in turn involves identifying the nature of the problem, generating a number of potential solutions to the problem and carrying out a means-ends analysis of the problem (Laboskey, 1994).

Schön (1983:22) distinguishes between reflection-in-action: 'reflection on phenomena, and on one's spontaneous ways of thinking and acting, undertaken in the midst of action to guide further action' and reflection-on-action: reflection on phenomena and one's actions after-the-fact. He refers to the kind of tacit, dynamic and spontaneous knowledge practitioners display when they are doing their work as "knowing-in-action". Knowledge-in-action is portrayed by "our skillful execution of the performance; and we are characteristically unable to make it verbally explicit" (Schön, 1983:25). Walking, for instance, is a form of knowing-in-action. It involves flexing and contraction of muscles, shifting the body's centre of gravity as is appropriate, adjusting the pace and many more complex activities. In spite of all these many activities involved in walking, we display a spontaneous and fluid performance of awareness, appreciation, anticipation, and adjustment. During this fluid and spontaneous performance, something may not go according to expectation. This may induce doubt, hesitation or even surprise us. This impels us to think intuitively in the midst of action when there does not seem to be time enough to reflect (Goodman, 1991; Schön, 1983). It is this form of reflection-in-action that characterises the artistry with which sense can be made out of the uncertain, unique and conflicting situations (Schön, 1983).

1.6 The classroom eco-culture and reward structures.

Although learning is ultimately idiosyncratic, it is rarely a solitary exercise, in that the learner is constantly interacting with the learning materials, the teacher and other learners to construct meanings (Bishop, 1985; Cobb, 1990; Watson and Marshall, 1995). These interactions are important determinants of learner outcomes (Penick and Yager, 1986). Reward structures describing instructional strategies teachers employ to encourage pupils to achieve certain outcomes have been a subject of research in the last two decades. The co-operative, competitive and individualistic pedagogical reward structures have been associated with achievement in science in general and in biology in particular (Michaels, 1977; Sharan, Daron, Hertz-Lazarowitz, 1979; Johnson, 1979; Johnson and Johnson, 1979; Okebukola and Ogunniyi, 1986; Sherman, 1988; Jegede, 1995; Watson and Marshall, 1995).

Viewed from both the personal and the social construction of knowledge perspective, learning can be seen to involve a variety of reward structures. At the personal construction level, learning is individualistic. Pupils as individuals process information and construct new knowledge independent of the teaching strategies that could be used (Barnes, 1976; Millar, 1989a). When pupils are motivated and are striving for mastery, finding it rewarding to reflect and resolve discrepancies between their conceptual ecologies and the scientific world view or when they are striving to out compete each other in order to complete assigned tasks, learning is competitive (Okebukola, 1986; Hewson and Thorley, 1989; White and Gunstone, 1989). However, when a group is working together, helping each other to accomplish the desired objectives, then learning in that regard is a co-operative endeavour (Johnson and Johnson, 1985; Slavin, 1987). These learning strategies have an important bearing on classroom practice. It is common place to see pupils working in small groups in biology classes to achieve the lesson objectives. The reasons for this are not hard to find given the shortage of equipment and the high cost of stocking laboratories with supplies and quite often the difficulty of acquiring supplies in some instances. While the classroom environment may favour co-operative endeavours in achieving educational objectives, the examination that overhangs the whole curriculum is highly competitive in that it is used to sift the able students who will get places to further their education from the overwhelming majority who are doomed to roam the streets.

It seems that the tension between the curriculum intent and practice cannot be ignored, neither can it be wished away. Hence, any teacher or pupil who ignores it, does so perhaps at his/her own peril. This is particularly important in a situation where the use of these teaching strategies does not seem to be geared towards enhancing learning outcomes, but more towards classroom control and management. Of course, this is not to suggest that effective management strategies do not have an effect on achievement, but rather that using these learning strategies to reach such ends may not be an efficient way of mobilising resources. This study, therefore, deems co-operative, competitive and individualistic reward structures to be potent strategies for enhancing tangible learner outcomes. As a result, it seeks to determine the effects of these teaching strategies and reward structures on students' achievement and participation in biology.

Co-operative models of instruction among other things, are believed to provide opportunities for expert "scaffolding" for the learners. This conceptual apprenticeship initiates the learner into the way of perceiving phenomena from a scientific perspective (Driver, 1989; Nussbaum, 1989; Driver, Squires, Rushworth, and Wood-Robinson, 1994). This is not limited to the teacher since pupils working in co-operative groups, can in a non-threatening way, help each other to conceptualise things they initially could not. Verbal interactions are also more likely to be increased when pupils work co-operatively, and this may enhance the process of construction of meaning (Webb, 1985; Reynolds, 1992).

In a co-operative model of interaction, students work together in small heterogeneous groups to complete a common goal (Johnson, 1979; Johnson and Johnson, 1979; Johnson, Johnson, Scott and Ramolae, 1985; Okebukola, 1986; Sherman, 1988; McCaslin and Good, 1992). Watson and Marshall (1995) identify two task structures often used in co-operative models of instruction as (i) task specialisation, in which each learner is assigned a specific responsibility to perform a particular aspect of the activity, and (ii) group study in which all members of the group are expected to work together to complete the task without having specifically separate responsibilities. In this positive goal interdependence model, all members of the group are rewarded equally when the desired goal is achieved.

It has already been mentioned that, some constructions of meaning are best done at personal levels. For example, in the individual reward structure system, pupils are given individual goals. The pupils cannot get assistance from others but the teacher. The achievement of a goal is independent of other students' and is evaluated in criterion-referenced fashion (Okebukola and Ogunniyi, 1984; Sherman, 1988).

In competitive interaction models, students are given individual goals, but compete with each other to achieve the goal. In this case, for one to succeed another must fail or perform at a lower level and hence the tendency to discourage each other from achieving the desired goal. In this regard, a norm-referenced reward system is used (Slavin, 1978; Okebukola and Ogunniyi, 1984; Sherman, 1988).

The influence of teacher behaviours on the pupils can either be direct or indirect (Okebukola and Ogunniyi, 1986). Direct teachers on the one hand, are more inclined to dominate instructional time presenting what in their opinion is worthwhile information. They would spend relatively more time directing and supervising students. In terms of student motivation, they are what Campbell (1970) refers to as "motivators toward avoidance of failure". They are much more dominant in the lesson, less warm and tend to make disparaging and reproving statements when they evaluate (Campbell, 1970). Indirect teachers on the other hand, are more likely to create a classroom environment in which pupils are more actively involved. They will empathise with pupils, acknowledge and reinforce pupils' responses and ask questions that challenge the students to think (Amidon, 1970). They are "motivators toward excellence" (Campbell, 1970). Their behaviour is characterised by friendly and pleasant relationship with the pupils, intellectual questioning, originality and creativity (Campbell, 1970). It would be expected therefore, that certain teacher behaviours should positively or otherwise affect students' participation and achievement in biology.

Whether direct or indirect teaching can or cannot enhance achievement is not conclusive. Some studies conclude that indirect teachers are more likely to enhance achievement (e.g. Citron and Barnes, 1970; Dillashaw and Yeany, 1982; Okebukola and Ogunniyi, 1986). In some cases direct teaching was found to favour enhanced achievement (e.g. Moon, 1971), while in other instances no difference was found between direct and indirect teaching (e.g. Houston, 1975). Besides, teachers' behaviours and their influence to enhance achievement in biology in Botswana are yet to be established. Information of this nature should prove to be useful towards finding ways of enhancing student performance in biology.

1.7 Statement of the problem.

The general economic recession of the 1980's has had far-reaching consequences on the provision and quality of education in Africa (Pendaeli, et.al., 1993; Ogunniyi, 1995). The science laboratories have gradually become ill equipped to be used effectively to teach science as an inquiry. The poorly paid teachers have either lost the creativity and enthusiasm in science teaching or have left their native countries for those with healthier economies at a perilous cost of brain drain to Africa. According to Ogunniyi (1995) and Nganunu (1988), Botswana albeit its inadequacies in science education, like insufficient trained science teachers and laboratory assistants, is an exception to the general trend in Africa. It has been mentioned earlier that, the conditions for learning have greatly improved over the years, particularly in terms of physical infrastructure. Even though this could be the case:

> There has been criticism about the standard of mathematics and science at the senior secondary level, as well as other levels of the education system. Despite provision of adequate facilities and resources for the teaching of science, the system still does not produce enough students with the necessary qualifications to pursue science-based programmes at the University level. Some of the factors responsible for this situation are the poor quality of instruction and lack of a clear science policy (Republic of Botswana, 1993:147).

Two issues arise from this criticism. The first is a trend of rapidly changing educational policy on the educational system from the 7-3-2-4 before 1986 to the 7-2-3-4 after 1986. The 7-2-3-4 system was supposed to be a transition phase to the 6-3-3-4. After the 1992 commission on education, the system of education changed back to the 7-3-2-4 system. While these changes are worthy of discussion, this paper would not focus on them. Never-the-less, it is worthy to note an observation by Mautle and Weeks (1993:10) that:

> It is a fallacy to believe that changing the structure will improve the quality of education or relieve societal problems such as unemployed school leavers. A structural change, which may be justified on one argument, may in reality have a series of unanticipated consequences.

Perhaps the fact that the education structure reverted back to the 7-3-2-4 system is a confirmation of this statement. The general populace voiced displeasure about the quality of the form two junior secondary school leavers (grade 9). The curriculum at this level was generally viewed as watered down and incapable of exposing the learners to sufficient content and process skills in science.

The second issue is fundamental in the sense that it appears that the adequate supply of equipment in the schools does not seem to bring about a concomitant improvement in the quality of instruction. There seems to be a dialectical relationship between the provision of instructional materials in the schools and the technical efficiency with which the teachers utilise these to realise instructional objectives. It is suggested that the decline in the performance of the students in science in Botswana secondary schools amidst adequate instructional inputs, may be explained in terms of the capacity of the teachers to manage and utilise the instructional inputs effectively. For this reason, this study focused on teacher behaviours. Of particular concern is to determine how teachers could mobilise the instructional inputs in such a way that students would construct meaningful knowledge in their classrooms.

1.8 Purpose of this study.

This study sought to explore patterns of teaching in biology lessons in Botswana and to determine the relative effects of exemplary teaching and learning materials on the students' participation and achievement in the subject. More specifically, the study attempted to determine the relative effects of co-operative, competitive and individualistic laboratory interactions on students' performance in biology.

In pursuance of this objective, answers were sought to the following questions.

1. What are the patterns of verbal and non-verbal interactions exhibited by biology teachers and students in selected secondary schools in Botswana?

2. What differences exist between the interaction behaviours of biology teachers and students involved in an exemplary teaching-learning model and those not so exposed?

3. What relationships exist between the students' sex and academic ability on the one hand and their level of participation and achievement in biology lessons emphasising exemplary practice on the other?

4. What are the relative effects of co-operative, competitive, and individualistic laboratory interaction models on the students' participation and achievement in biology lessons emphasising exemplary practice?

To answer questions 1-4 above appropriate hypothesis were posited for testing as follows:

1. There are no discernible patterns of verbal and non-verbal interactions exhibited by biology teachers and students in selected secondary schools in Botswana.

2. There is no significant difference between the interaction behaviours of biology teachers and students involved in an exemplary teaching-learning model and those not so involved.

3. There are no significant relationships between the students' sex and academic ability and their level of participation and achievement in biology lessons emphasising exemplary practice.

4. There are no significant differences in the effects of co-operative, competitive, and individualistic laboratory interaction models on the students' participation and achievement in biology lessons emphasising exemplary practice.

In addition to testing relevant null hypotheses, a "thick" qualitative description of the data was done to provide a balanced analysis.

1.9.1.0 Significance of the study.

Many developing countries have now made major strides in realising the basic education for all. In Botswana, education is free though not yet compulsory at the primary and secondary school levels. This has provided access to increased numbers of students in primary and secondary schools. These increased enrolments, coupled with dwindling economies resulting in less resources to support education, and the deteriorating quality of teacher training and preparation in most developing nations have resulted invariably in declining quality of instruction (Fuller and Heyneman, 1989; Chapman and Snyder, 1990). Science education is viewed as a major force driving economic development (Jensen, 1989, Ogunniyi, 1995). Improving the quality of instruction in science is therefore seen as a necessary factor to develop the human power base needed to sustain economic development. One of the plausible ways of improving the quality of instruction is by improving the content and pedagogical knowledge of the teachers (Chapman and Snyder, 1990).

In 1990, "classroom research" emerged as one of the five priority research areas suggested in a research seminar organised by the Ministry of Education in Botswana for senior officers from various departments of the Ministry. According to the Ministry of Education (cited in Mosenodi, 1993, Vol. 1 (1): 65-66), researchers in this area need to

> continue research on student interactions...identify ways to facilitate students' participation in learning; studies on the availability and use of materials in the classrooms; examine time management in the classroom; identify variables that affect the quality of teaching; identify examples of good teaching; produce models of excellence in classroom instruction...

The main assumption here is that effective teaching is likely to lead to higher student achievement (Chapman and Snyder, 1990; Ogunniyi and Ramorogo, 1994).

As indicated earlier, what constitutes effective teaching depends on the context in which it is treated. It is justifiable, however, that certain qualities widely agreed upon by practitioners, experts and students in the discipline, from the literature can be taken to reflect exemplary practice in a given context. In other words, exemplary practice in this sense does not imply the ideal but one worthy of being imitated or serving as a good illustration or a frame of reference. This has not yet been done in the case of biology teaching in the context of Botswana. Models of excellent teaching and learning can also be identified within the constraints or otherwise of the context within which they exist. This is particularly important at this period in time when students are no longer seen as "preserving teacher knowledge" but as "constructing socially situated knowledge" (McCaslin and Good, 1992).

The socio-cultural environment of the pupils determine to a large extent the interaction patterns that will enhance their achievement and participation (e.g. Jegede, 1995). The teacher's worldview can extensively affect the learning atmosphere in the classroom (e.g. Cobern, 1996). Traditionally in Botswana, when the speaker is speaking, one does not interrupt with questions (Tlou, 1971). If this happens to be the worldview the teacher holds, then it would not be surprising that when the teacher speaks, the pupils are silent. The opportunity for children to ask inquiring questions is completely eliminated. According to Wragg (1994), this phenomenon is very common in animal communities. Members of the community learn their place within the social structure, and keep to their territory. Students who find themselves in this kind of environment will quickly learn their "place" in the instructional process and this may marginally limit the responsibility they can assume for their own learning through active construction of ideas during the lesson.

One of the four national ideals in Botswana is self-reliance. In villages and rural areas, this ideal has translated into many community projects like roads, schools, post offices and community halls being built by communities coming together and collectively working towards the completion of the projects. Many community junior secondary schools and the University of Botswana have been built through such co-operative efforts. It is also not uncommon to find farmers collectively building a communal dam to water their animals or to find a group of people helping to build a kraal or thatch a hut. Competition is also a common phenomenon, though for a different reason. For instance, it is not a usual practice for people to reveal the number of cattle they have for the fear that someone who hears about it may become jealous and so bewitch them (Ramorogo, 1992). A boy who tends cattle well or a girl who keeps the house well gets the approval of the parents and children even within the same household tend to compete for such approval. While the effects of eco-cultural variables on learning outcomes have been studied elsewhere (Humphreys, et.al. 1982; Okebukola, 1985; Okebukola and Ogunniyi, 1986; Jegede and Okebukola, 1990; Burron, James and Ambrosio, 1993; Chang and Lederman, 1994), this investigator is not aware of any such study in Botswana. It is hoped that findings in this regard might prove to be informative and useful.

1.9.1.1 The importance of context in exemplary practice.

Exemplary teaching and learning environments in science education are characterised by management strategies that encourage sustained on-task behaviour, active student participation and deep understanding of concepts (Tobin and Fraser, 1990; Stage and Bol, 1996). The co-operative, competitive and individualistic teaching strategies have been used to engender, at least in part, these qualities in exemplary classroom settings. Student achievement has been unequivocally used to determine the effectiveness of such strategies in the learning/teaching situations. As, pointed out earlier, the results of such studies are inconclusive.

This inconclusiveness may be explained in terms of the contexts in which learning was to take place. It is not clear in what contexts these teaching strategies were used. In view of the fact that contexts vary from one classroom to the other, each classroom is unique and has its own social environment. Thus, in each classroom, the learners have their own ways of associating, behaving and of doing things. The teacher also, has his/her own beliefs and ideas about learning which influence the way he/she interacts with the learners and influence their behaviours. Under such diverse settings, the type of socialisation and prior ideas is likely to affect the achievement of students in a variety of ways. Context, in this sense, is a critical factor motivating this study.

1.9.1.2 Classroom discourse in the context of exemplary practice.

The importance of talk in mediating learning has been discussed earlier. There is a plethora of studies on the nature of teacher-student talk and its relationship to learning. This study, however, bemoans the dearth of studies that focus on student-student talk and how it may relate to academic cognitive gains of the students. This type of talk can be viewed as a continuum. At one end of the continuum, are situations where students' discourse in small groups occurs amidst heavily, teacher dominated classroom verbal interactions. In such situations, the importance of small group interactions is not related primarily to the construction of meanings by the students, but rather such an arrangement may be motivated by the acute shortage of apparatus or other teaching materials. The teacher in this arrangement is still central in transmitting worthwhile knowledge and as such, the need for students to work in small groups is seen as part and parcel of the overall transmission of this knowledge to the learner. The motivation for the ensuing student talk therefore, falls short of providing opportunities for students to construct their knowledge. Instead, such talk is better understood in terms of helping students to commit more knowledge to memory. Hence, students are more inclined to approach problems to be solved with questions of this nature in mind: "is this what is supposed to happen?" or "what are we meant to discover?" (Driver, 1983:3; Woolnough and Allsop, 1985:10). Of course, this type of talk is not likely to involve the students in any deep cognitive involvement with the problem since it was not planned to achieve such involvement. Rather, students would be trying to reproduce what is acceptable to the teacher or what they think are acceptable scientific facts. In other words, students' interpretations and the meanings they attach to the discourse are important determinants of what they would learn.

At the other end of this continuum, talk can be envisioned within the framework of a deeper conceptualisation of concepts. This is the type of discourse espoused in this study. Students do not only co-operate to accomplish the task assigned to them, they, to a large extent, co-operate to create their own knowledge. Teacher talk is kept to that which is necessary to scaffold, lead, challenge deeper thinking, and motivate the students. In this regard, students, through discussions, debates and presentations, negotiate meanings and ideas. They are encouraged to let loose their creativity and to realise that there are alternative ways of perceiving and solving problems. Discourse, in small group work, in this sense, is motivated by the need to explore and resolve the disparities between the new information and the students' already existing knowledge. Language as a context of learning in this way, may to a great extent, determine what the learners can successfully learn.

1.9.1.3 The context of practical activities in exemplary practice.

Practical work as alluded to earlier can be used to serve various purposes. However, space limitation would not permit a more detailed discussion of these. It suffices to note that the role of practical work to enhance learning in science education is being increasingly questioned (e.g. Driver, 1983; Solomon, 1986; Hodson, 1988;

Woolnough, 1991). This however, is not to imply that practical work has no potential at all to enhance cognitive gains in science education, but rather, that the reasons for using practical work need to be carefully considered before it is used. The importance of this, stems from the fact that practical work done with little regard for deeper understanding of the concepts often fails to engender the construction of meanings and ideas by the students. As such, even when the students could do the experiments, they would still lack the insight into the problem (Novak, 1990).

The underlying assumption is that students' meaningful discourse with the learning situation is a necessary context within which worthwhile practical work takes place. What is implied here is that, practical work is not concerned primarily with giving the students experiences of phenomena in question, but rather with giving the students meaningful insights into the problems that they are investigating. Students have to make sense of their experiences in biology lessons in order to construct their own knowledge. In other words, the context in which learning is to take place should dictate the full realisation of such a construction of meanings.

The way the learning materials are structured and presented to the students may enhance or hamper their process of knowledge construction. As such, exemplary learning materials should be structured in such a way that they encourage the students to think about their thinking (Howe and Tompsen, 1989). Thus, the learning activities should be structured as collaborative efforts in which students can share ideas in an environment that is more conducive to experimentation and risk taking as in small groups (Greenfield, 1997). In other words, the learning materials should encourage the process of making sense of the experiences afforded students by practical activities. For this to happen, Gunstone (1991) argues that the students would need to spend less time interacting with apparatus and spend more time interacting with ideas.

1.9.2 Delimitation of this study.

The educational system in Botswana consists of seven years of primary education, two years of junior secondary education, three years of senior secondary education and three-four years of tertiary education (i.e. 7-2-3-4). The Commission on Education in 1994, recommended a change from the current 7-2-3-4 system to a 7-3-2-4 system by 1996. This study was confined to form three (grade 10) students. Currently, this stream of students is in the first year of their three-year senior secondary school education. This group is assumed to be suitable for this study for the following reasons; (i) the classes contain a largely heterogeneous group of students, (ii) students are just beginning their three year course and teachers are more likely to agree to expose them to the treatment because they are not yet under pressure to complete the syllabus, (iii) the classes are more likely to contain more or less equal numbers of boys and girls because at this stage all the students have to do integrated science, they select their different science options after form three, (iv) since Community Junior Secondary Schools (CJSS) are to a large extent comparable in terms of equipment, facilities, quality of teachers and equity in terms of students' access to admission, the pupils in form three have a fairly homogeneous science back ground (Kahn, 1990).

The schools participating in this study were only those that have been offering Cambridge Ordinary Level School Certificate (COSC) for at least three years and displayed comparable performance. The teachers participating had at least three years teaching experience and were recommended by both students and other teachers as particularly competent teachers. These had to be teaching at least two form three classes so that a pre-test could be administered to one class while the other goes without.

The study was limited to schools which could be reached by a two wheel drive vehicle and to areas where distances between schools could allow two to three schools to be visited a week. The study therefore, was limited to clusters of schools in and around Lobatse, Gaborone, Palapye/Serowe, and Fracistown areas. Data on the pupils and teachers perceptions of exemplary practice and the dominant pedagogical interaction patterns, however, were extended beyond these limits since the investigator did not need to spend extended periods of time with the respondents.

The contexts in which teaching or learning materials can be assumed to be exemplary are multifarious and in no way exhaustive. This study was limited to identifying the dominant pedagogical paradigms, models of exemplary teaching in biology lessons, exemplary classroom environments and the effects of a student-teacher-material interaction model on the performance and achievement of students in biology.

CHAPTER TWO.

2.0.0 Review of literature and the theoretical framework.

The aim of this study was to explore the patterns of teaching biology lessons in Botswana and to determine the relative effects of exemplary teaching and learning materials on the student's participation and achievement in the subject. Teaching and learning in general have, for a long time been of interest to educators, psychologists and philosophers of education. A variety of viewpoints have, therefore, been expressed on this subject. Cohen (1983) describes teaching as a variegated activity that can take many forms, from formal to informal and subject-centred to student-centred. For this reason, terms like team teaching, effective teaching, exemplary teaching and others are common place in the educational literature.

Fenstermacher (1986) describes what Soltis (1978) calls the 'generic-type-analysis' of the term teaching involving: i) at least two people i.e., the teacher and the learner; ii) one of them possesses or should be capable of possessing something (content) which he/she intends to pass on or transmit to the other who does not possess or only possesses a little of this thing; iii) these two enter into a relationship for the purpose of the learner acquiring the content. Fenstermacher (1986) also contends that such a relationship represents the generic meaning of teaching. As one may note, the generic concept of teaching does not involve itself with whether or not the learner is willing to receive the content, the way the content is transmitted to the learner or whether or not the learner actually learns anything from this association. Also, the fact that the one who possesses knowledge intends to 'transmit' it to the learner falls short of the post-epistemological concept of knowledge construction by the learner, which down plays the role of logic and empirical testability in preference for the affective and relative truths. An attempt to address these concerns inevitably results in variations in the focus of teaching hence the need to explicate the generic concept of teaching. In turn, this results in the development of alternative concepts like exemplary teaching and others. The concept of learning too, has evolved over time. It has been perceived differently by various theorists and practitioners since the time of behaviourism to the era of constructivism. The concept of exemplary teaching and learning espoused in this work is no less a product of such an evolution.

2.1.0 Theoretical framework.

In order to provide the appropriate research context for the study, a number of theories of learning that have a bearing on exemplary teaching and learning is discussed. Within the cognitivist paradigm, Ausubel's subsumption theory, Carl Rogers' theory of self-concept, Sternberg's theory of intelligence, Piaget's theory of cognitive development and Vygotsky's social cognitive theory of learning are discussed with particular emphasis on how they provide a frame of reference for exemplary teaching and learning practices as portrayed in this study.

2.1.1 Historical development of constructivism as a theory of learning.

Behaviourist approaches to teaching view learning as developing certain patterns of behaviour. Consonant with this notion of learning is a view of teaching as a means of increasing repetition of particular responses whenever appropriate stimuli are applied. To encourage repetition of approved responses, appropriate reinforcement or reward is given whenever the organism (in this case the learner) displays the approved response to a stimulus (Cohen, 1983). Theories built around this notion of teaching are instrumentalist in nature in that they tend to focus on the teacher rather than the learner (Cohen, 1983). Their focus is the acquisition of certain skills or the exhibition of expected behaviours and not on the processes through which the learner constructs viable knowledge. The following behaviourist theories seem to exemplify this perspective quite graphically.

2.1.1.1 Stimulus - Response Theory.

a. Connectivism.

During the early decades of the twentieth century, E. L. Thorndike developed a theory of learning that assumed a link between specific stimuli and specific responses through what he called an 'S-R bond'. According to this theory, learning was purported to have occurred if certain impressions are associated with specific impulses to action (Knoers, 1994). The association of a stimulus and a specific response came to be known as a 'bond' or 'connection'. To strengthen or to break the behaviour, the connections would either have to be strengthened or weakened as well. This theory came to be known as "connectivism". Thorndike did not see learning as solely resulting from the occurrence of the stimulus and the response at the same time, but also on other factors following the response. Two of the major laws he formulated are the law of effect and exercise. The former states that a connection can be strengthened or weakened depending on whether it was followed by satisfying conditions, for instance a reward for desired behaviour (Higard and Bower, 1948; Hills, 1979; Cohen, 1983; Knoers, 1994). The latter considers practice to be a necessary condition to strengthen connections. In other words, drill and practice strengthen bonds.

b. Principle of Frequency and Recency.

John Watson just like Thorndike viewed learning as coming from without. His main interest was on how thought and emotion manifested itself in behaviour. His work was geared towards reducing complex behaviour into S-R units. He put forward the principles of 'frequency' and 'recency' (Hills, 1979). Frequency had to do with the notion of repetition. The more often one responds in a particular way to a given stimulus, the more likely he/she would attempt to repeat the response later when the same stimulus is given. The principle of recency had to do with the fact that if we had just responded to a particular stimulus in a given way, we are more likely to respond like that again should the stimulus be repeated a short time later.

c. Operant conditioning.

B. F. Skinner considers reinforcement to be necessary for learning to occur. He suggests drill practice instead of "frequency" as a factor that enhances the student's chances of remembering a particular response and that 'recency' occurs only when the conditions reinforce the behaviour (Hills, 1979). Skinner differentiated between two kinds of behaviour. Like earlier behaviourists, he believed that some behaviours are elicited by the application of specific stimuli. This type of behaviour he terms 'Respondent' behaviour. This follows a stimulus from 'outside'. He noted that certain behaviour is actually initiated by the organism and is spontaneous, for example walking, talking and so on. This he called 'Operant' behaviour, and it was his main concern. He focused on how it could be controlled and modified. Learning in this perspective involves alteration of behaviour. Operant conditioning, according to Skinner shapes the learners' behaviour in the same sense a sculptor shapes a lump of clay (Cohen, 1983).

It is worth noting that Skinner started drawing attention to the fact that the learner is capable of performing certain behaviours without an external stimulus. That is, a realisation that knowledge could come from the organism itself. Philosophers like Rouseau had also adopted this view. This view differs from the Aristotelian notion of the mind as a bucket to be filled or a blank sheet of paper to be imprinted on with knowledge by the teacher. It also differs from Bacon's theory of induction whereby the learner simply 'reads the book of nature' or perceives the 'real world' by 'grasping with his/her senses'. According to Rouseau, teachers only need to consider the stages of development that all children undergo and transmit to them that which they are ready to receive (Perkinson, 1993). The essence of this argument is recognition of the role of the learner in the learning process.

It is interesting to note that when Skinner (a behaviourist) developed the theory of Operant conditioning, he was essentially responding to a limitation of the stimulus-response view of learning in which the learner is seen as a passive element acted upon by the environment. He rejects classical conditioning as an inadequate account of learning. He believed that as much as something is done to the learner during the learning process, the learner also does something. His idea of Operant conditioning viewed the learner as operating upon the environment.

A common link among the behaviourist theories is that they do not see the learner as an important factor in the learning process. The learner is construed as a relatively passive element that will modify its behaviour once the appropriate stimuli are applied. Behaviourist theories are silent about the processes that occur within the individual as he/she learns new material. In other words, 'learning' is viewed as a demonstration of the desired behaviour in a situation where reinforcing stimuli are presented (Knoers, 1994).

Operant conditioning, though recognising the role of the learner in the learning situation, is not free from treating the learner as an object to be manipulated. Cohen (1983) suggests that pigeons for example can be taught to play Ping-Pong through operant conditioning. But the more they get better at it, the less they are pigeons but objects behaving in a strange, alien and pre-selected manner - which in the pigeons point of view is essentially meaningless.

2.1.2 Implications of behaviourism on teaching and learning.

The effect of behaviourist theories on the teaching and learning of science cannot be ignored. Classrooms are still thronged with scenes of students chanting the times table, repeating the teachers utterances and generally working on exercises that provide an opportunity for the students to repeat a concept many times with the hope that this will enhance the chances that such a concept is committed to memory. It is not uncommon to find a situation where the teacher introduces a topic, for instance, measurement of length, after which the students will be required to go around the classroom measuring the lengths of various things. This practice seems to espouse the behaviourist notions of drill and practice, recency and frequency.

Knowledge, according to the behaviourist theories resides somewhere outside the learner. Bacon accordingly contends that 'we read the book of nature'. It is through exposure to nature that we will receive this knowledge. Two issues arise as a result of this notion. First is the role of the teacher. If knowledge does not reside in the learner, then it is in the teacher, probably in the books too. For this reason, the teacher tends to be perceived as a source of uncontested information. Second, is the way in which this knowledge is passed on to the learner. The teacher is considered to transmit in a non-problematic way the knowledge to the learners who passively receive it.

2.2.0 Gestalt psychology and functionalism.

Recognition of the cognitive features as important determinants of learning is further portrayed in the Gestalt theory of learning. Gestalt is a German word meaning figure, configuration or form (Knoers, 1994). The figure can only be visualised if it is standing against a background. The background comprises prior experiences that help to give the figure its structure. The learner would act to the best of his capability to achieve an insightful solution to the problem, provided that the problem is within the limits of what the learner can achieve (Hilgard and Bower, 1948). Learning then, consists of getting the insight and discovering the structure against the background of prior knowledge.

John Dewey (cited by Perkinson, 1993) argues from an evolutionary point of view and perceives learning in terms of adaptation. To him, learning involves solving problems that one meets in order to attain certain ends or goals. According to him knowledge is not received by the learners but rather discovered. Teachers should therefore, structure the learning materials, which are suitable for the level of development of the students, such that they can discover the knowledge that they should attain. This he portrays in his principle of 'learning by doing' which espouses the fact that the learning outcomes are greater if students experience phenomena by active and personal involvement (Kourilsky, Quaranta and Lory, 1987). Although Dewey did not seem to go beyond viewing learning as coming from without, he (like the Gestaltists) recognised the role of active participation by the students.

2.3.0 Piaget's epistemological constructivism.

The work of Jean Piaget diverged from the work of the previous thinkers in two major ways. First, he used clinical methods to explore the children's thinking and second, he was concerned with the reasons behind the children's beliefs and ideas. Central to his developmental theory was the idea that individuals actively construct knowledge. Unlike the Behaviourist who construe knowledge as reception or the Gestaltists and Functionalists who regard knowledge as discovery, Piaget, (like other constructivists e.g. Vygotsky) regard knowledge as construction by the individual as he/she interacts with the environment.

Piaget identifies four stages of development each with a definite cognitive-logical structure and in a fixed sequential order. An individual remains in a particular cognitive stage as a result of a partial adaptation to the environment. This adaptation is a result of some degree of equilibrium between the individual and the environment. One remains in this stage until the equilibrium is disturbed. To reach this equilibrium again, the learner has to assimilate the environment into his/her cognitive structure and also adapt the cognitive structure to the environment.

Learning is an adaptive process involving accommodation and assimilation. This implies that one learns by doing and this is not limited to physical action only, it also includes mental activities. Acquiring knowledge involves disturbing the original equilibrium because the knowledge may conflict with what is known. The activities involved in learning are meant to counteract this disequilibration.

2.3.1 Accommodation and Assimilation.

The organism incorporates new experiences into the existing schema through a process of assimilation. To incorporate new schemata, concepts and categories into the cognitive structures involves the act of judging, interpreting or bringing the object under a category (Kitchener, 1986). These schemas can then be modified to resolve problems arising from new experiences within the individual's environment - a process of accommodation. This is an active process characterised by exploration, questioning, experimentation, trial and error and reflection. This goes on until successful new schema are arrived at (Beard, 1969).

Kitchener (1986) argues that accommodation and assimilation should not be seen as independent and sequentially occurring, rather as reciprocal and simultaneous processes. Accommodation involves adjusting the structures to the object as assimilated, and assimilation entails incorporating the object into accommodated structures. When viewed this way, it is possible to talk of adaptation - a situation that arises when a certain degree of reciprocal balance between accommodation and assimilation is reached. At this point, the disparity between the learners' cognitive structures and the cognitive environment would have been resolved.

2.3.2 The role of social interaction in Piaget's theory.

Piaget (1970) identified four factors as crucial for his theory of cognitive development. These are maturation, interaction with the physical environment, social experiences and equilibrium (Forman and Cazden, 1985). Piaget considers equilibrium to be the most fundamental of these. This is because of the importance of equilibrium in determining cognitive development. It requires disequilibration to progress from one stage of cognitive development to the next. Piaget tends to focus more on peer interaction than on student-teacher interaction. Peer interaction and social interaction in general become important because of the nature of impact they can have on the student's state of equilibrium. That is, they are capable of introducing cognitive conflict that may result in a state of disequilibration. Epistemologically speaking, the role of other individuals in a learning situation is that of a hindrance which results in reflection which in turn, is followed by a construction of the reasons for the statement (Kitchener, 1986).

2.3.3 The contribution of Piaget's theory of cognitive development to this study.

Piaget's theory of cognitive development draws attention to the role of the learner in the learning situation as a cognising being and not a passive recipient of teacher transmitted knowledge. It portrays the learner as intelligent. This intelligence can be increased by exposure to problem-solving situations.

Knowledge is acquired not through rote learning methods but by active construction. The learners have control and are responsible for their own learning (Fox, 1993). Content therefore, should be presented to the learner such that it encourages construction of meaning. Learning is also considered as a personal activity that requires interaction with the environment. The interaction with the environment provides social experiences that lead to cognitive growth. Central to the learning process is activity by the learners. In other words, the learning situation should allow for the learners to interact with concrete materials to internalise ideas and to develop their thinking skills (Fox, 1993). Since a learner goes through the stages of development in a sequential order, the new knowledge and ideas should be suitable for his/her level of development. A mismatch between a learner's cognitive development and the demands of the learning materials may create learning difficulties.

2.3.4 Limitations of Piaget's theory in relation to exemplary teaching and learning.

As alluded to earlier, Piaget concentrated more on peer interaction than the interaction between the student and the teacher (Kitchener, 1985). It therefore, marginalises the role of the teacher. In the context of a developing country like Botswana where the science curriculum is centralised and the national examinations are used to select a limited number of students for placement into tertiary education, the role of the teacher in mediating learning is an important one.

The role of peer interaction is considered to be that of introduction of cognitive conflict so that disequilibration results. Considering peer interaction from this perspective involves looking for evidence of overt cases of conflict, for example, arguments. This theoretical stance is helpful in explaining instances where conflict is depicted clearly in external social behaviours. In situations where overt conflict is not evident but cognitive apprenticeship prevails, this theory remains unclear about cognitive development in such instances (Forman and Cazden, 1985).

The role of language as a mediating factor during internalisation of knowledge is not given prominence in Piaget's theory. This falls short of perceiving internalisation as a social process. It also gives inadequate clues about the role of semiotic mechanisms that mediate learning, especially the language (Wertsch and Stone, 1985). The role of language in acknowledging the conflict to oneself and to others and also in resolving that conflict is also not clear. As a result, Piaget does not provide clues on how students could be helped to develop cognitive abilities in the classroom. Neither is it clear in his theory whether it is the changes in the language or in thinking that forms the backcloth to development (Fox, 1995).

Piaget's conception of learning also ignores the learner's social and culture milieu in the sense that the role of peers is viewed in terms of hindrance other than construction of idiosyncratic knowledge. As such, social medium from which the learner acquires the vicars of his culture is downplayed. This constitutes a profound difference between his view and Vygotsky's paradigm of interiorisation. The way in which the social and cultural factors affect the learner's perception and hence shape the learner's cognitive structure is not considered. This is particularly important because how the learner perceives an object as incompatible to his/her cognitive structure is a product of his/her socialisation.

2.4.0 Ausubel's theory of meaningful learning.

Meaningful learning entails acquiring new meanings, which in turn and conversely are the products of meaningful learning. As such, when new meanings are realised by the learner, it indicates that a meaningful learning process is completed (Ausubel, 1968). Meaningful learning occurs if what is learnt can be associated in a nonarbitrary, substantive fashion to the learners existing cognitive structures (Ausubel, 1968).

According to Ausubel (1968), both reception and discovery learning can be either meaningful or rote. In both cases, meaningful learning results if the learner displays a meaningful learning set. That is, when the learner is in a condition to relate the new learning materials in a non-arbitrary and substantive fashion to the cognitive structure. The material to be learnt too should have the potential to be related to the cognitive structure in a non-arbitrary and non-verbatim fashion.

2.4.1 The relevance of Ausubel's theory of learning to exemplary practice.

Ausubel underscores the importance of prior knowledge in the learning process. Teaching should be concerned with creating a meaningful learning set for the learner. This involves establishing what the learner knows and then using that as the basis for presenting new materials to the learner. Where the learner does not have any prior experience, teaching should involve establishing advance organisers for the learner. That is, giving the learner appropriate knowledge that may be related in a substantive and non-arbitrary fashion to the new knowledge.

Learning is an active process. Pupils should be given opportunities to be involved actively in the learning process both mentally and physically. Pupils should be allowed opportunities to think and to discuss ideas so as to make sense of the learning tasks. And learning tasks presented to the learners should have a potential to be learnt meaningfully. As such the learning tasks should be relatable to what the learner already knows at that particular time of development. The role of the teacher in determining the learners' existing cognitive structures and facilitating meaningful learning is an important one. The teacher is also central in creating a conducive learning environment that would encourage meaningful learning.

2.4.2 Limitations of Ausubel's theory of meaningful learning to exemplary practice.

Ausubel much like Piaget does not seem to emphasise the role of social interaction and culture in the learning process. The role of language in mediating learning is also down played in this theory of meaningful learning. Yet, the culture, language and the psychosocial environment of the learner are some of the critical variables associated with the learning of science (Aikenhead, 1997; Cobern, 1997; Ogunniyi, 1997; Tobin, 1997)

2.5.0 Bruner's theory of learning.

A divergent view in the study of perception from the foregoing studies was put forward by Jerome Bruner. His concept of perception was in part a reaction against behaviourism and psychoanalysis. These schools of thought were seen to undermine the unique forms of problem solving evident when students are given more challenging tasks. The stimulus-response approach as espoused by behaviourists was seen as inadequate to account for the complex behaviour of students who are engaged in the process of concept attainment, problem solving or language production (Bruner, 1973). Psychoanalysts with their emphasis on the unconscious drives portrayed an individual as an emotional and irrational organism and failed to account for his/her potential to consciously and deliberately manoeuvre his/her environment.

Bruner (1973) argues that it is important that the thought processes should be portrayed with the complexity and rationality that characterise them. In contrast to behaviourism and psychoanalysis, perception does not only result from the stimulus determinants but also experiential, motivational, personal and social factors. Also, the perceiver should not be seen as passive and indifferent, but as one who actively selects information, forms perceptual hypothesis and often distorts input in the process of concept formation (Bruner and Postman, 1950; Bruner, 1973). His central concern was the process through which people select, retain and transform information (Anglin, 1973). From a theoretical perspective, he was concerned with how individuals construct internal models through which they can predict, extrapolate and find out and use appropriate information that is not readily provided to solve problems.

Bruner(1960) also emphasises the structure of the subject as central to the learning process. He contends that grasping the structure of the subject implies understanding the structure in a way that allows the learner to relate many other things to it in a meaningful way. An understanding of the structure predisposes the learner to understanding the relationships between concepts and ideas. What is learnt can be useful to the learner in future in two ways: In the first instance, it can be specifically useful in performing tasks that are very similar to what has been learnt - direct transfer of skills. For instance, in the event of using the skills one learnt of taking a reading from voltmeters with scale divisions of 0.1 and 0.01 volts respectively. This kind of utility is limited because it does not allow the learner to go beyond the information given.

In another situation, previous learning can affect the efficiency of later performance through the transfer of principles and attitudes. It entails learning a general idea as opposed to a skill. This general idea then serves as a template against which related ideas are recognised. Bruner (1960) maintains that this type of learning is responsible for continuity in learning because for one to appreciate the applicability of an idea to a new and novel situation, he/she must have initially fully comprehended the general nature of the problem in question.

The value of interest in the learning process is also recognised. The argument is that the learner's interest in the subject is enhanced if the subject is rendered worth knowing. That is, making the knowledge that the learner has acquired useful beyond the level of skill application. The knowledge should give the learner a leading edge when dealing with more novel situations demanding knowledge other than what was initially acquired. Further, learning is seen to be more than just an acquisition of general principles. It also involves the 'development of an attitude to learning and inquiry, toward guessing and haunches, toward the possibility of solving problems on one's own' (Bruner, 1960:20). It takes not only a mere presentation of ideas to achieve this, but also a sense of excitement about discovery on the part of the learner - when the learner ultimately discovers similarities between ideas that were previously not seen as related (Bruner, 1960, 1966).

2.5.1 Implications of Bruner's theory of learning on exemplary practice.

Bruner de-emphasises the role of rote learning. Learning should involve the development of attitudes toward inquiry. Learners should be able to make intelligent guesses and haunches and to test their haunches. Learning involves more than acquisition of skills. It also involves a construction of ideas about the world around the learner. Learning, therefore, should be able to extend the learner's cognitive reach when dealing with new situations involving ideas related to those already learnt. Materials to be learnt should be presented to the learner in a modest way. When materials are presented to the learner at a particular age, the task of teaching is to present the materials to the learner such that it represents the structure of the subject in terms of how the learner views things at that age.

The role of the teacher is important in the mediation of learning. If learning involves learners exploring their guesses and haunches, then the teacher serves an important role of minimising the risks and severity of the consequences of such exploration. Exploration in this sense involves allowing the learners to commit errors during their learning process and the role of the teacher is that of 'increasing the informativeness of error' (Bruner, 1966). When the learner fails to reach the desired ends, the teacher should make clear to the learner what it is that produced failure.

2.6.0 Vygotsky's social cognitive theory of learning.

This theory recognises the role of culture and that of the teacher in learning. The teacher guides and transmits culture to the students. Teaching involves establishing what the learner can do and then through appropriate and adequate instruction help the learner to achieve higher learning outcomes than expected. Thus, the teacher helps the student to explore the "zone of proximal development". The argument here is that 'Human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them.' (Vygotsky, 1978:88).

An individual exists in a symbolic world. A world that consists of conceptually organised, rule-bound belief systems about reality, about how to achieve goals and about what is of value (Bruner, 1985). It appears that, for one to successfully master this world, the aid and assistance of others are important. The guidance of a competent peer or adult is necessary until the learner gains conscious control of his actions. In Vygotsky's own words, the zone of proximal development is,

> the distance between the actual development level as determined by problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (1978:86).

In order for the learner to put his/her actions under conscious control, he/she must first possess the function to be put under control. Conscious control on an action only develops at a later stage in the development of the function. In other words, by the time a function is used consciously, it should have been used and practised unconsciously and spontaneously (Vygotsky, 1934; Bruner, 1985). For the learner to use and practice the function unconsciously, someone needs to be the source of this vicarious form of consciousness. In classroom learning situations this would be a competent adult or peer. The tutor performs the function of 'scaffolding' until the learner is able to internalise the knowledge as thus converting 'it into a tool of conscious control'.

2.6.1 Language, thought, and the process of enculturation.

According to Bruner (1985:23), Vygotsky views language as a means of sorting out how one thinks about things. Consequently, he was interested in how the social environment of the learner shaped his mind, with language as a mediating factor (Fox, 1995). While Piaget seems to down play the role of language in the development of thinking, Vygotsky believes it is the development of language that underpins the development of thinking. Thinking organises perception and action. Language influences our thinking, which in turn informs the way we perceive things and our concomitant actions. Language plays two roles in knowledge acquisition. One role is that of social contact which involves communication with other members of the society. The other is that of representation - a process that aids the processes of interiorisation (Stones, 1983; Davydov and Radzikhovskii, 1985; Lee, 1985; Fox, 1995). Language in this sense is used to facilitate thinking. Language is initially directed to others but at a later stage it is consciously used to control one's own thoughts and actions. As a result, it mediates both the social and the individual functioning of the learner (Davydov and Radzikhovskii, 1985; Wertsch and Stone, 1985; Fox, 1993).

It is through language both as a medium of social contact and as representation to oneself that the individual is initiated into the culture of the society. As a means of communication, the child, through language, learns to present ideas to others and to receive information from others. And as a means of representing phenomena, a child learns to attach meanings to phenomena as governed by the norms and values of the society that raises him.

Play is an important aspect of Vygotsky's theory in that it develops in the child the uniquely human forms of motivation. It allows the learner a 'zone of proximal development' and through this the child creates new motivations as well as attitudes toward reality (Lee, 1985). The crucial aspect of a child's cognitive development is separating thought and language (Fox, 1993). The child, through play, attaches meaning to an imaginary situation and this meaning is what guides his/her actions. When this happens, the child starts to cut off the link between a thing, a situation, and an action (Lee, 1985). For instance, in childish kitchens, when a child uses a tin to cook soil, both the situation and the actions are imaginary. The child creates meanings to suit her/his actions; a tin becomes a pot and soil becomes porridge and a symbolically mediated desire controls the nature of reality at the time. Reality conforms to what the child wants to perceive and how she/he wants to act as is dictated by the idea represented and not the objects in question (Lee, 1985; Fox, 1993). A tin ceases to be a tin but a pot because it has to be engaged in the general idea of cooking. At this level, language is representative to the child because she/he uses language to represent reality to him/herself - a tin represents the word pot.

2.6.2 The relevance of Vygotsky's theory to exemplary practice.

The idea of teacher mediation and of the zone of proximal development raises two important concerns when viewed from the background of a developing country like Botswana. Considering the fact that children are unique individuals and develop at different rates, and as such will reach their 'zones' at different times, raises the first problem for the classroom teacher who is faced with teaching a class of more than thirty-five children. The problem is, how best could the teacher cater for these different zones within the given teaching time.

At a different level, one may consider the role of language in mediating learning. This could be at a level of teacher mediation where teacher - pupil talk is of central importance (see, Prophet and Rowell, 1990). Without re-inventing the wheel, language can also be considered at a level of peer collaboration where it is used to negotiate ideas and meanings amongst collaborating peers. The latter consideration, which is the less discussed in the extant literature is the focus of this study. Here teacher mediation is viewed in terms of creating a conducive environment for pupils to construct their ideas in small groups.

The role of social interaction is not viewed in terms of looking for evidence of conflict as in a Piagetian perspective, but rather in terms of evidence of mutual guidance and cognitive apprenticeship between the teacher and the learner; a situation whereby the teacher and other collaborating learners are viewed as providing a framework in which a child can perform beyond the given, due to the cognitive support provided.

The social environment should encourage the internal mediation of mental processes. As such, the exemplary teaching and learning materials should provide the pupils with opportunities to think and to reach consensus about what they are doing. Learning is seen as a personal construct that is socially mediated. As such, the exemplary learning materials should be structured such that they do not only provide students more managerial roles like being the leader of the group, performing certain task of the learning activities or being the recorder for the group, but also, provide them with more cognitive roles (Lumpe and Starver, 1995). In other words, the learning materials should afford students opportunites to think and talk about what they are doing.

2.6.3 The limitations of Vygotsky's theory to exemplary practice.

While Vygotsky's ideas do not take cognisance of the situational and contextual factors that affect learning, they are worthy ideas in that they have drawn the attention of scholars to: i) the active intellectual involvement of the learner during the learning process and ii) the shift in the role of the teacher from transmitting knowledge to facilitating learning.

Vygotsky's theory paved the way for varied perceptions of the ways in which learners are perceived to construct knowledge. However, it still perceives the learners as invariant and textureless beings. In this way it fails to take into consideration the role of the learner's perceptions of the social, cultural and contextual factors on knowledge acquisition.

2.7.0 Carl Rogers' theory of self-concept.

If learning is perceived to be a personal construct, then it becomes important to consider whether the learner views himself/herself as an important and able actor in the learning environment. Carl Rogers believes that people have the innate tendency and the desire to grow, to perform optimally and to realise their full potential (Cooney, Cross and Trunk, 1993). It is important that the learner assumes responsibility for his own learning. This is more likely to happen if the learner believes that he/she has the potential to influence the learning process. This involves an awareness of one's beliefs, values and attitudes. These collectively form a person's self-concept (Fox, 1993).

The development of the self-concept is not a solitary endeavour, it is a product of social interaction. It results from an interpretation of how others react to one's behaviour. According to Rogers (1983) and Fox (1993), interaction with other people is a vital ingredient in the development of the learner's self-concept because of the feedback the learner gets. It is from such a feedback that the learner would know what is socially acceptable and what is not. Parents, teachers and peers are important features of the learning environment in that they act as mirrors that reflect the learner to himself/herself.

2.7.1 The role of parents and teachers in the development the self-concept.

The way the learner perceives himself/herself is not stable. It changes depending on the interaction with others and the feedback he/she gets from such interactions. Rogers (1983), argues that parents and teachers can enhance the learners perception of the self by according the learner, love that is not based on his/her successes and failures - 'unconditional positive regard'. As a result of this unconditional acceptance by significant others, the learners will accept themselves and be more open to new and challenging experiences (Cooney, Cross and Trunk, 1993).

Learners spend most of their time in the classrooms with teachers and peers. The classroom therefore, is central in forming the learner's self-concept. The learners may gain some confidence in themselves if teachers give them praise and consistent feedback. While feedback would help shape the learners self-concept, it does not adequately account for the overall self-concept of the learner (Fox, 1993). From a phenomenological perspective, the way the learner perceives and interprets feedback is also important. The meanings learners attach to feedback are influenced by their prior experiences. Consequently, the same phenomenon can be interpreted in different ways depending on the nature of prior knowledge the learner possesses.

From this point of view, significant learning is possible, particularly in the presence of a teacher. Significant learning presupposes that knowledge exists primarily for use and that learning should make a difference in one's behaviour, choices in the future, attitudes and personality (Cooney, Cross and Trunk, 1993).

2.7.2 Conditions for learning.

Cooney et.al. (1993) identify five conditions necessary for learning as suggested by Rogers. These include i) facing the problem - this involves a realisation by the learner that he/she is up against a serious and meaningful problem. The learner could have been working on this problem and is aware that he/she is not very successful.

ii) Congruence - the necessity for the therapist to be real in his relationship with the client. The therapist should be freely, deeply, and acceptably the person he/she is. He should be aware of his/her feelings and experiences and match them well with his/her responses. In a sense, he/she can show enthusiasm, frustration and other feelings as he/she interacts with the situation without imposing them on the learners.

iii) Unconditional Positive Regard - an un-reserved caring for the client for what he/she is. Caring that is not limited to the good aspects of the client only but also a deep feeling of acceptance even if it involves the 'client's expression of negative, 'bad', painful, and abnormal feelings...'(Cooney et. al., 1993).

iv) empathetic understanding - the therapist should understand the client's point of view empathetically. That is, the therapist should genuinely identify with the client's perspective of the world.

v) the client should be able to view the relationship between himself/herself and the therapist as that of congruence, acceptance and empathy. Successful communication of these to the client is an important aspect of the development of the client's personality and self-esteem.

2.7.3 Implications of Carl Rogers' theory for exemplary teaching and learning.

While this theory was developed primarily with the psychoanalytic therapeutic climate as a focus, it has important implications for education as well. It is suggested that for significant learning to occur, the learner must be in contact with a situation that is perceived by the learner as problematic. The learner does not need external motivation in this case. The realisation that there is a problem to be solved will naturally bring learners together to solve the problem. The learning environment should as much as possible make allowance for the learners to be in contact with real life problems that concern them and as such are willing to solve.

According to Cooney, Cross and Trunk (1993), the role of the teacher is to create a learning environment conducive to significant learning. Aspects of such an environment include: i) the teacher's realness - where the teacher is the person he/she is, accurately aware of his/her feelings and is not a faceless facade of a curricular requirement nor a sterile conduit through which knowledge is transmitted from one generation to the other; ii) The teacher should create an atmosphere of acceptance and understanding in which the learners should feel accepted for what they are and the teacher would understand the feelings they possess; iii) the teacher should be responsible for provision of resources; resources not in the sense of laboratory equipment etc., but in terms of using himself/herself, his/her knowledge and experience as a resource (Cooney, Cross and Trunk, 1993). The teacher would make the pupils aware of his/her rich experience and knowledge in the field and that it is available to them, yet he/she would not want them to perceive him/her as a source of uncontested knowledge.

2.8.0 Theories of intellectual competence.

There seems to be marked differences in the effectiveness with which individuals perform tasks that are intellectually demanding. It appears that such differences result, at least in part, from the basic differences in the individual's cognitive abilities. There is a trend among the cognitivists to suggest that the individual's cognitive abilities are not static. They appear to change as one acquires more cognitive skills. Consequently, the individual's intellect appears to be dynamic. Intelligent behaviour seems to depend on how well one can adapt behaviour relative to experience in order to cope with the environment. To understand intelligence, one might have to understand the basic processes that underlie intelligent behaviour.

Intelligence is one concept that is used a lot without a clear articulation of what it actually means. There seems however, to be a relationship between intelligence and thinking. Perkins (1989) perceives intelligence as a product of neurological efficiency and the knowledge and skill the individual has acquired. The neurological component of intelligence might not be affected by education since it refers to the physical structures of the brain and their innate ability to cope with the tasks of cognition. In that sense, it is largely a matter of inheritance.

2.8.1 Sternberg's theory of intelligence.

Sternberg (1981) considers intelligence as a set of developed thinking and learning skills that one tends to use in academic and daily life problem-solving situations. These cognitive skills can be separately diagnosed and taught. The list of such cognitive skills is neither exhaustive nor mutually exclusive. He lists the following as representative of such cognitive skills. i) Problem identification - the ability to identify the problem to be solved. This could possibly be a necessary step to successful problem solving. ii) Process selection - the ability to select the appropriate set of cognitive processes necessary for one to solve the problem successfully. iii) Representation selection - this results when one can represent information in a useful way both to oneself and to others. iv) Strategy selection - involves selecting a strategy for sequencing the processes in order in which they will act on the representation. v) Processing allocation - involves appropriate time allocation to the various tasks that should be performed. vi) Solution monitoring - a sense of awareness about what has been done, what is being done and what has to be done. It also entails a constant monitoring of the skills that have been applied to the tasks in a way that leads to the solution of the problem. vii) Sensitivity to feedback - Whether one can improve on what he/she is doing depends to some extent on how she/he perceives feedback and how well that feedback is used to influence performance of the tasks. Feedback can be internal, that is, be derived from one's own perception about one's performance, or external, for instance, when other people make comments about your performance. viii) Translation of feedback into an action plan - It does not always follow that if one receives feedback, that feedback will be effectively used to improve performance. The individual needs the ability to plan how to put feedback to use in order to improve. ix) Implementation of the action plan - It is not enough to plan and not carry out the plan. Once the plan to improve performance has been drawn, it needs to be carried out.

2.8.8.1 Importance of Sternberg's theory to exemplary practice.

Learning and thinking skills can, potentially at least, be taught. Teaching and learning should encompass creating opportunities for the learners to acquire such cognitive skills. This involves, at least in part, providing the learners with opportunities to engage the processes that are characteristic of intelligent behaviour.

Assessment of cognitive development should include assessment of the processes of intelligent performance and not solely the product of such behaviour as is normally the case.

2.8.8.2 Limitations of Sternberg's theory of intelligence in relation to this study.
This theory appears to treat the learners as invariant beings, as such does not seem to adequately recognise the role of the learners prior experiences on his/her perception and interpretation of the problem which will in turn determine the strategies, process selection and even the time allocation to the various stages of problem solution.

It is important to recognise that theories of learning in general, continue to have some influence on the development of curricula, teaching strategies selected and used by teachers and also on the belief systems of teachers about teaching and learning albeit at considerably different levels. It has been mentioned earlier that this work is set within the constructivist theoretical framework. Therefore, to put it into context, it is important to consider the current state of contemporary constructivism.

2.9.1.0 Constructivism as a theory of learning.
Constructivism is a postepistemological theory of learning that construes learning as an adaptive, interpretive process. It is not a theory of teaching and as such does not describe teaching. Teaching approaches, however, can be abstracted from a constructivist theory of learning and used as constructivist teaching techniques (Roth, 1993; Tobin, Tippins and Gallard, 1994; Driver, 1995; von Glasersfeld, 1988, 1991, 1995; Gergen, 1995). It is a set of beliefs about knowing and knowledge that can be used to explore the learning potential of any learning setting, and as such, can be used as a referent to inform classroom activities that would maximise opportunities for learning (Tobin, Tippins and Gallard, 1994).

Constructivism as a theory of learning is both postepistemological and post-structuralist (Doll, 1993; von Glasersfeld, 1995). It is postepistemological in the sense that it does not condone the traditional theories of knowledge which portray knowledge as representing a real world that exists, separate and independent of the knower (von Glasersfeld, 1995). Rather than focusing on knowledge as a representation of the truth, constructivism focuses on the processes of constructing viable knowledge (Tobin and Tippins, 1993). While the truth is absolute and in positivist paradigms can be tested empirically in the natural world, the constructivists hold that truth is relative and can be tested semiotically by submitting any proposition to a group of informed and competent holders of what may prove to be different constructions (Guba and Lincoln, 1996). Thus, it rejects the claims for epistemological certainty. Hence it advocates that knowledge cannot be taken to reflect an ontological objective reality as the picture of the world. From this perspective, knowledge does not serve the function of representing independent reality, but rather an adaptive one (Confrey, 1995; von Glasersfeld, 1995). This is however, not to deny the existence of a reality. While constructivism acknowledges the existence of a reality, it holds that we can only come to know of such reality in a personal and subjective way (Tobin and Tippins, 1993).

It is post-structuralist because instead of characterising the structures and stages of thought or isolating and modifying behaviour learned through strengthening S-R bonds, it is concerned with understanding and describing the processes which results in deeper conceptual understanding and the development of cognitive structures

(Fosnot, 1991). Constructivism is a non-positivist psychological theory of learning in which behaviours are not central in the process of instruction but rather instruction is concerned with concept development and deeper understanding of phenomena. As such it often stands at odds with behaviourism (Fosnot, 1991; von Glasersfeld, 1995).

2.9.1.1 The various facets of constructivism.

While constructivism was advocated by the likes of Piaget, Vygotsky and others over sixty years back, it only gained wider acceptance as a philosophical orientation about a decade ago (Thompson, 1995). It appears that expressions like "children's ideas," "construction of meaning," "prior knowledge," are increasingly becoming part of the language of science education. The wider acceptance of constructivism as a theory of learning was not without consequences. It appears that as it became a popular theory of learning, it got open to various interpretations (von Glasersfeld, 1984; Bettencourt, 1993; Thompson, 1995). Strike (1987) and Duit (1995) observe that constructivism seems to be used in the discourse of science educators much like the word 'democracy' is used in political circles. Whatever democracy is, it is presumed to be a good thing, but whether or not any two people using this word mean the same thing is questionable. The same goes for constructivism. Since it has come to be viewed as a fashionable and fruitful theory of learning (von Glasersfeld, 1993; Duit, 1995), some of the tenets of constructivism are only articulated in a sense that emphasises a superficial orientation to the theory.

2.9.1.2 Radical versus trivial constructivism.

von Glasersfeld (1984) distinguishes between radical constructivism and naive constructivism. According to von Glasersfeld (1984, 1993), since constructivism became the catchword in science education, it has been adopted by people who do not intend to make an epistemological shift. Such people view constructivism mainly in terms of the requirement of prior knowledge for learning to occur (Tobin and Tippins, 1993). Such a dubious perception of constructivism, is what von Glasersfeld refers to as trivial or naive constructivism. Duit (1995) and Thompson (1995) argue that the unreflective adoption of trivial constructivism has an unfortunate, inherent tendency to invite misinterpretations and this has had and continues to have undesirable consequences. For instance, the notion of constructing knowledge on the basis of already existing ideas may lead to the conception that the world is solely idiosyncratic (Duit, 1995).

Radical constructivism is an endogenic theory of knowledge. It lays emphasis on the mental processes of the individuals and on the way knowledge of the world is internally constructed (Gergen, 1995). It acknowledges the existence of external reality but posits that cognising beings can only know that reality in a subjective way (Bettencourt, 1993; Tobin and Tippins, 1993; Confrey, 1995; Gergen, 1995; von Glasersfeld, 1995b).

According to Confrey (1995), radical constructivism; i) rejects the theory of learning that depicts learning as a process through which we are progressing towards an increasingly accurate view of how “things really are” in an independent, external world and ii) realises that in order to know something, one has to act on it. Knowledge is a product of our actions (Confrey, 1990). Hence, knowledge involves actions and reflection on such actions. It appears that knowledge viewed from this perspective could not be separated from knowing (Tobin and Tippins, 1993). Learning is not a passive reception of knowledge through the senses. Knowledge cannot be transplanted into a person's mind. It therefore does not reflect the real world as it is, but rather, the individual transforms experiences to construct a viable world in his/her physical environment (Cobern, 1993; Roth, 1993; Gergen, 1995).

2.9.1.2 Weaknesses of radical constructivism as a theory of learning.

Radical constructivism is an endogenic theory and as such it views knowledge as fully interiorised. That is, the learning process can be accounted for in terms of internal cognitive processes and not the external ones. While this seems to absolve radical constructivism from the scylla of dualism, the monistic nature of this perspective exposes the theory to yet another perilous problem; that of solipsism (Strike, 1987; Duit, 1995; Gergen, 1995). Once the world is seen to be solely idiosyncratic, it would appear there would be as many worlds as are cognising beings. To portray the world as a construction by one's own mind seems to suggest that what we see as the world is actually of our own design; the "world" and "others" in it are nothing but our own creations. How one manages interactions with his own creation remains unclear and whether or not there is indeed a potent world to challenge our adaptive capabilities remains suspect (Duit, 1995; Gergen, 1995).

Gergen (1995) goes on to observe that in an attempt to circumvent the problem of solipsism the radical constructivists add a pragmatic dimension to the theory. Thus, the role of cognition is seen to be adaptive and primarily serving to organise the experiential world (von Glasersfeld, 1988). Of course, to talk of an 'adaptive' process within a monistic theory needs qualification, and von Glasersfeld (1988:87) argues that "The concept of adaptation intended here is the basic biological concept in the theory of evolution. It refers to the *fit* with the environment..." Gergen (1995) argues that there should then be a separate and independent environment to which the individual should adapt. Hence the endogenic account for knowledge and knowing does not seem to be sufficient. The endogenic perspective, therefore, should be coupled with an exogenic concern about the world into which the individual fits.

2.9.1.4 Contextual constructivism.

As argued earlier, constructivism does not view learning as a matter of transmitting knowledge to the learner. Rather, learning is seen as an active construction of knowledge by the learner. The metaphor of construction lucidly and aptly summarises the epistemological perspective adopted by constructivists that the learner actually builds the knowledge. A construction site is usually typically characterised by the tools of the trade, the foundations, materials and the personnel who carry out the construction process. The environment in this case would be conducive for construction work to proceed. Primarily the depth and nature of the foundation normally dictate the nature of the building. In a sense, not just any building may be erected on just any foundation. Construction of knowledge from a contextual constructivist perspective is done on a foundation, in addition to the beams and studs of prior knowledge (Cobern, 1993). The context forms the foundation on which construction of knowledge occurs.

Solomon (1987) placed emphasis on the role of social interaction as a context for learning. She argued that the ideas students hold about nature are not a product of the logical processes the scientists use in their investigations but rather of the 'common sense' attitude that relies on being able to share perspectives and meanings with others. The argument is that, as the students interact with each other and the teachers, they develop ideas that they hold in common and hence share common meanings in classroom discourse. Context is an important component of the learning process and social interaction is an important context in which learning may occur (Cobern, 1993).

2.9.1.5 Social constructivism.

One of the major criticisms levelled against the work of Piaget is that he did not place much emphasis on social interaction in his theory. von Glasersfeld (1995), however, argues that this is unjustified because Piaget, in almost all his books, would somewhere reiterate the importance of social interaction in enhancing opportunities for accommodation to occur.

Constructivists perceive learning as a social process. Learners make sense of experience in terms of their extant knowledge (Tobin and Tippins, 1993). Experience in terms of sensory input makes sense to the learner if it is associated to the learner's extant knowledge. As a result, the process of sense making is shaped by the experiences of the learner and is mediated in a socio-cultural milieu. The learners construct knowledge through active cognition. Such cognising learners, however, exist only in a socio-cultural sense (Tobin and Tippins, 1993; Tobin, Tippings and Gallard, 1994). Construction of knowledge is not a solitary exercise, it takes place in the presence of others who potentially may perturb the situation in a way that, such perturbations become integral aspects of the learner's experiences.

Science, its thought, forms, concepts and concomitant language encountered by the students in the school context is alien to the culture and language of learners alike, especially those to whom English is not the first language as in the case of Botswana (Fensham, 1988; Ramorogo, 1992; Ramorogo and Wood-Robinson, 1995). Science classrooms are contested cultural sites where the teachers initiate the students into the culture of science. Thus the students are initiated into the language of the subject, its special ways of observing, writing and ways of doing things. Learning in this perspective is a process of enculturation where the understanding of a concept and its meaning are developed through a process of social interaction in which the learner negotiates ideas with teachers and other peers (Roth, 1993).

2.9.1.6 Constructivism: the backcloth to exemplary practice.

The literature is replete with studies on effective teaching. Most of these studies have attempted at enumerating the traits of an effective teacher. More recently, other process and product variables associated with effective teaching have been studied (Kyriakou, 1986). One major problem common to these studies on effective teaching, is related to the issue of producing an unequivocal set of characteristics that describe effective teaching. A review of the literature shows that effective teaching does occur in a variety of ways characterised by invariably different qualities (Kyriakou, 1986). For this reason, the current study assumed a social constructivist approach to explore exemplary practice in biology lessons in Botswana. Despite a lack of comprehensive theory of constructivism (Black, 1989) there are a number of working hypotheses or guides which have proved to be informative and useful to curriculum development and instructional practices (Howe and Thompson, 1989).

A behaviourist-positivist approach to learning (Gallagher, 1993) with emphasis on hands-on activities where the teacher's role is to transmit scientific knowledge and skills to the students belie the constructivist approach to learning (Ogawa, 1986; 1989; Prophet, 1990; Fuller and Snyder, 1991; Ramorogo, 1992; Cobern, 1993; 1996; Ogunniyi and Ramorogo, 1994; Jegede, 1995). Constructivism views the meanings that individuals construct in the process of making sense of the world around them as being critical in the learning process (Driver and Oldham, 1986). Learning in a constructivist sense is an adaptive process in which pre-existing ideas strongly influence the meanings attached to new knowledge (Hewson and Thorley, 1989; Nussbaum, 1989; Driver, 1989b; Cobern, 1991). The learner is actively involved in a process of sense making over which he/she has some control (Driver, 1989b). The responsibility of the learner in this sense is not to learn the knowledge transmitted by the teacher (Gallagher, 1989) but to actively construct meaning of the experiences and phenomena. This synthesis of ideas involves elicitation, clarification and construction of new ideas that is unique to each cognising being (Millar, 1989a; Tobin and Tippins, 1993).

Beyond the personal construction of knowledge, ideas must also be seen to be viable in the social and physical milieu in which the learner exists. In as much as knowledge is constructed individually, it is socially mediated (Tobin and Tippins, 1993). From this perspective, a curriculum is embedded in a cultural matrix from which it cannot be separated (Ogunniyi, 1988; Wheatley, 1991). This cultural matrix include a body of accumulated knowledge and understandings, skills, beliefs, values, customs, taboos, myths and other learners (Wheatley, 1991; Bettencourt, 1993; Thaman, 1993). These are important constructs that shape the images of contexts in which particular meanings are constructed. It follows therefore, that in order to create a learning environment in which learners can take responsibility over their own learning, much of the current teaching practices will have to be re-considered. Exemplary teaching and learning environment in this sense should be such that students feel free to ask questions, share their ideas with other students and the teacher. They should also be able to test the validity of their ideas against those of their peers and against the scientific worldview. It should be noted at the same time that in a constructivist sense, there is no one prescribed way to teach and to learn. Different ways of teaching can be expected to be appropriate in different contexts and that science should therefore, be taught in whatever way that holds promise for meaningful learning (Millar, 1989a; Tobin, 1993).

Active participation by pupils in exemplary practice is not necessarily synonymous with "hands-on" activities because experience is not an end, but a means to an end; the end in this case being the sense that pupils make of the experience. This involves both the personal and the social construction of knowledge. It may involve pupils working individually on a problem, or reflecting on a familiar experience that is related to the idea discussed in the lesson. Imagination in this regard is an active intellectual process since it plays an important role in construction of meaning (Driver, 1983; Ramorogo, 1992). A scenario of 'vocal teachers and silent pupils' need not necessarily portray pupils as passive recipients of information as a lot of imagination and mental modelling can possibly be taking place in their mind. It seems that a well-planned exposition used creatively can provide opportunities for construction of knowledge by the pupils. For the same reason it seems crucial to explore what teachers do in their classrooms and why they do what they do (Koballa and Crawley, 1990; Fuller and Snyder, 1991). Once the metaphors, beliefs and values teachers hold about teaching and learning have been explored, one is in a better position to identify and design teaching models compatible with a teacher's predisposition to a given school subject. The inherent challenge, however, is how to challenge the beliefs, metaphors, and values teachers hold with the demands of exemplary teaching.

2.9.2.0 Empirical findings.

One of the main aims of science education is to equip teachers with pedagogical skills. This is particularly important at this time when the traditional objectivist methods of teaching are no longer considered adequate to meet the objectives of curricula which views learning as an adaptive process where pupils are continuously constructing ideas for themselves (Ogawa, 1986; Ogunniyi, 1986; Driver, 1989b, 1995; Bettencourt, 1993; Cobern, 1993; Tobin and Tippins, 1993; Roth, 1993; Ogunniyi and Ramorogo 1994; Confrey, 1995; Duit, 1995; Jegede, 1995; Thompson, 1995; von Glasersfeld, 1995b; Fadock, et.al., 1996). It can be assumed that if teachers are well trained, they will be able carry out instructional tasks effectively. This is however, not to say that trained teachers are automatically effective teachers.

Teachers, just like their students, construct meanings about the learning and teaching process which are informed by their interactions with other teachers, the society, the pupils, and the curriculum in terms of instructional materials at their disposal and of course, the examinations. Teaching science in this sense is an adaptive social process of making sense of experiences the teacher gets during the interaction with the teaching learning process (Ogunniyi, 1986; Driver, 1989b; Lorsbach and Tobin, 1992; Ogunniyi and Ramorogo, 1994; Wildy and Wallace, 1995; Fadock, et.al., 1996).

It follows then that exemplary teaching is a correlate of the teachers' content and pedagogical knowledge, and personal traits such as enthusiasm, creativity, motivation, level of commitment and management capability (Ogunniyi, 1986; Marope, 1992; Ogunniyi and Ramorogo, 1994). It is apposite, therefore, to assume that in any classroom situation both the teacher and the pupils bring pre - conceived ideas about teaching and learning. These in turn inform their views about the curriculum and the way it is supposed to operate (Bowen, 1994). For this reason, whatever goes on in the classroom does not solely depend on how the teachers conceptualise teaching but also on (i) the students' perceptions about their learning and the role the teacher should play in the learning teaching situation and (ii) the environment in which science is learnt (Roth and Roychoudhury, 1994; Ogunniyi; 1995)

There is a plethora of studies on the factors that affect achievement in science. Achievement seems to be the starting point in defining school quality (Fuller and Heyneman, 1989). Early studies in this area heavily relied on the sociological analytical traditions (Lewin, 1992) in which the individual's socio-economic background was seen to be the main single factor influencing achievement than any other (e.g. Coleman, et.al., 1966). They were heavily informed by the production-function models of the economic theory in which achievement can be explained in terms of the human and material inputs into the learning situation (Brophy and Good, 1986; Snyder and Fuller, 1990; Fuller and Snyder, 1991; Lewin, 1992). These models tend to explain achievement in a simple linear relationship between inputs (e.g. textbooks, writing materials, chairs etc.) and outputs, in this case pupil achievement (e.g. Duncan, 1985, 1989; Mwamwenda and Mwamwenda, 1987; Baine and Mwamwenda, 1994).

While there is evidence that a significant variation in the achievement of pupils in developing countries can be attributed more to the basic school inputs than the background of the pupils in science (Fuller and Heyneman, 1989; Fuller and Snyder, 1991; Lewin, 1992), such studies are limited in that they fail to explain how these inputs interact with the pupils to enhance achievement. In a sense, how the material inputs (e.g. textbooks, pens and pencils) influence the behaviour of both the pupils and teachers in such a way that achievement is enhanced, still remains unresolved. As a result, such studies remain to a large extent not helpful to the teachers who would benefit from the more concise details of how to mobilise resources in the classroom to attain enhanced achievement.

To explore this "black box", systematic observation of lessons dominated research programs and this led to the development of instruments that coded observable classroom behaviours (Flanders, 1960; Solas, 1992). Process-product research programmes relied on these to decide the effectiveness of given teaching methods and to make *post-facto* assumptions about learning (Solas, 1992).

Simon (1968) suggests two forms of interactions in the science classroom. They are (i) the verbal interactions where the teacher uses the chalk and talk exposition, and the non-verbal interactions where the pupils interact with the learning materials. Kyle, et.al. (1979) investigated the specific student behaviours displayed by the students in introductory and advanced level laboratories in botany, zoology, chemistry, geology and physics and concluded that students spend a lot of time listening to teachers transmitting knowledge.

In a study to examine the children's attributes and achievement-related evaluations in competitive, co-operative and individualistic reward structures among 400 students Ames and Felker (1979) found that amongst others, students place more value on achievement outcomes in the competitive goal structure than in the co-operative and individualistic goal structures. They also found that when students were successful in a competitive setting, this elicited higher ability attributions and was associated with more effect than when the success is achieved in a co-operative setting.

In a study investigating the relative effects of direct and indirect teaching on the achievement and participation of pupils in biology amongst fifteen pre-service biology teachers in Nigeria (Okebukola and Ogunniyi, 1986) concluded that the indirect verbal influence of the teacher created a learning environment in which the pupils felt free to participate. The pupils exposed to indirect methods of teaching were found to achieve better results and to participate more than those in the direct group.

Prior to this study, Okebukola and Ogunniyi (1984) in a study involving 1025 junior secondary class three (grade 9) students and 12 science teachers sought to determine whether or not there existed any significant differences in cognitive achievement and in the level of acquisition of practical skills among students exposed to co-operative, competitive and individualistic learning conditions. They found that the students exposed to the co-operative learning situation performed better on the cognitive achievement measure than those in other two categories. The students in the competitive group however, performed better than others on practical skills.

Watson (1991) investigated the effects of co-operative learning on the achievement of high school biology students on a sample of 715 students instructed by 11 volunteer teachers. The co-operative learning strategies produced significant outcomes when compared with the traditional method. In a comparative study of the effect lecture and co-operative learning strategies on achievement involving 68 general chemistry students, Banerjee (1997) found no significant differences in the achievement of the students using the lecture and co-operative learning strategies. There was also no significant difference in the performance of both sexes. Lazarowitz et.al. (1994) with a sample of 120 students concluded that co-operative strategies alone are not adequate to enhance students' achievement and that when co-operative learning strategies are incorporated into the mastery learning approach, the students gain in both academic and non-academic ways. Basili and Sanford (1991) investigated whether or not there was a significant relationship between group work and conceptual change using a sample of 35 students and concluded that co-operative group work can provide a conducive environment for adult learners to overcome their misconceptions in chemistry.

In a study to determine whether or not there exists a significant difference between the achievement of the students in two biology lessons exposed to co-operative and competitive structures respectively, Sherman (1989) concluded that none of the two structures was superior to the other. Chang et.al. (1994) after exposing a sample of 141 students to co-operative learning strategies for six weeks found that co-operative learning had very little effect on students' achievement. Likewise, Burron et.al.(1993), after exposing 51 students to it for 16 weeks report that the co-operative goal structure has no significant effect on academic achievement.

Using a sample of 116 elementary education majors at the University of East Carolina to investigate the effect of co-operative incentives and heterogeneous arrangement, Marshall and Watson (1995) found that group and individual accountability in co-operative settings makes no difference in the achievement of students. Their results did not support either the use of co-operative incentives or heterogeneous arrangement as means to enhancing achievement. Stevens et.al. (1991) however, found that combining co-operative incentives and individual accountability seemed to offer the most instructionally effective model of co-operative learning.

Clearly, whether the co-operative, competitive and individualistic teaching and learning strategies enhance learning remains inconclusive. The situation is undoubtedly complex. One limitation of studies in this area is that they seem not to explore the teachers' underlying belief sets about the teaching-learning process. Yet, such beliefs may affect the learning outcomes and the teaching approaches adopted by teachers. For instance, Tobin, Robbie and Anderson (1997) in a study to investigate the belief sets embedded within the discursive practices of the teacher and the students in a physics class found considerable disparities between teacher beliefs and their classroom practices. The teacher perceived teaching and learning in terms of constructivism, believed in students' autonomy in the classroom, and structured activities in such a way as to promote active student participation in the learning process. His/her actual classroom practices, however, emphasised goals that were not commensurate with constructivism, such as the use of formulas to perform calculations and memorising facts. Also, the enacted curriculum seemed to be shaped by other belief sets including among others the scarcity of time, the concern to cover the content and the need to prepare the students for examinations.

With the exception of Okebukola and Ogunniyi (1984) and Watson (1991), the sample sizes of a considerable number of studies appear too small for comfort if any worthwhile generalisations are to be made. Also, most of these studies adopted the process-product approach, and hence are limited in shedding any light on how co-operative, competitive and individualistic settings engender behaviours that enhance achievement. This could be what the practitioner in the classroom needs to know in order to improve the classroom craft. Even studies that used observation schedules to categorise classroom behaviours are limited in that they still cannot explain the assumptions in which the teachers' classroom behaviours in science classrooms are embedded.

Some studies attempted at exploring the effects of the teacher's content knowledge and the student's eco-cultural environment on the level of participation and achievement of the pupils. Carlsen (1993) in a study of four novice biology teachers to investigate the effect of the teacher's subject matter knowledge on the discourse control, concluded that teachers talked more in lectures when they were more subject matter knowledgeable than when they were not too sure of their subject matter. In the laboratories however, teachers talked less when they knew their subject matter very well. The rate at which teachers asked questions was highest in topics where the teacher knew little of the subject matter.

Jegede and Olajide (1995) in a study involving a total of 13 integrated science teachers to determine whether or not there exists any significant relationship between wait-time, classroom discourse, and the influence of socio-cultural factors conclude that teachers who allowed for a long wait-time tend to lecture less, ask more questions and exhibit more confidence. Teachers who allowed little or no wait-time at all tend to portray authoritarian leadership and in general tend to spend most of the time lecturing while students are quietly listening.

Using a sample of 128 secondary class four students to explore the effects of eco-cultural influences on student's concept attainment in science, Okebukola and Jegede (1990) found that students who lived in predominantly automated environments out-performed those from predominantly manual environments and that a preponderance of magical and superstitious reasoning significantly lowered the performance of the pupils in the latter as opposed to empirical reasoning.

Webb (1982) investigated the relationships among individual and group characteristics, interaction, and achievement in mixed ability and uniform ability small groups of students in mathematics. Using a sample of 77 students, he found that the more a student asked a question or made an error and failed to receive an explanation, the worse was that student's performance and the more often a student gave an explanation or received an explanation in response to a question or error, the better was the student's performance.

Amongst other things, a considerable number of the studies do not reflect the views of the teachers and the students who happen to be the main actors in the learning and teaching situation. They tend to consider talk in classrooms in terms of typologies like teacher talk and pupil talk and classroom interactions as verbal or non-verbal. In this sense the intent and context of such talk is lost. This reductionist approach to language in the classroom results in the loss of meanings and ideas that were communicated between students and the teacher. Hence they fail to reflect how language in group settings influence cognition.

While most of the foregoing studies are quantitative in nature, there has been a resurgence of qualitative interpretive studies exploring classroom life in science in the recent past. This is probably a realisation of the powerful effect that the environment under which the student learns has over educational progress (Wiseman, 1973).

Garnett and Tobin (1988) undertook an interpretive study involving two chemistry teachers, one using whole class method while the other used small group and individual approaches. They found that the effectiveness of these teachers could be attributed to their effective classroom management skills and their strong science knowledge background, which enabled them to employ teaching strategies that facilitated student understanding. They also asked questions that were appropriate and responded to the students' questions. Responding to students' questions is likely to enhance understanding since students' questions often signal lack of understanding.

Tobin and Fraser (1990) report findings of a study involving 13 researchers using a sample of 20 exemplary teachers and a comparison group of non-exemplary teachers. They found that exemplary teachers (i) used more management strategies that sustained student engagement, (ii) used strategies aimed at increasing the students' comprehension of science, (iii) utilised strategies that engendered student participation in learning activities and (iv) maintained a classroom environment conducive to learning.

While these studies shed some light on the complex and rich classroom ecologies, it is suggested that the validity of these results could be threatened by Hawthorne effect and of course the "Henry" effect since it is not evident from the reports that these were controlled for. The studies also tend to portray authoritative teachers as exemplary. No doubt, the situation is complex. In a certain socio-cultural setting some modicum of authority on the part of the teacher is inevitable if meaningful learning is to take place while in another context an authoritative posture might be counter-productive. Certainly, more studies are needed to provide more insight in the area.

The disparity between the performance of girls and boys in science classes has a long disturbing history. Studies based on the social learning model have attempted at explaining this gender gap in terms of the social learning model. This model places emphasis on the social environment of the learner. In which case, what the learner may learn is determined by the socialisation of the learner. The relative strength of such an approach hinges around the fact that it is this socialisation that the learner brings to the learning situation. Beyond this, it does not account for the way the learner interprets the learning – teaching cues and processes.

Using a sample of 213 fifth – and sixth grade students from 10 science classrooms taught by five different teachers, to examine the gender differences in the students' confidence, motivational orientations and use of meaningful and rote learning strategies in science, Meece and Jones (1996) concluded that girls were less confident in their abilities than boys and that only low-ability girls reflected less motivation to learn that their did male counterparts. In terms of the desire to learn science, there was no significant difference between girls and boys.

Some studies indicate that the nature of science as a masculine subject (Kelly, 1985; Sjoberg and Imsen, 1988; Haggerty, 1995) may be responsible for the under-achievement of girls in the subject. Hazel, Logan and Gallagher (1997) using a sample of 114 first year physics students who participated in the study of gender, language and assessment reported that boys performed significantly better than girls in multiple choice questions.

Evidence abounds indicating that intervention seems to reduce the gender differences in the achievement of boys and girls in science. Freedman (1997) in a study to examine the relationship among laboratory instruction, attitudes toward science and achievement in science knowledge of the students enrolled in a ninth-grade physical science course, found that laboratory experience had a positive influence on the students' achievement and attitudes toward science.

Lagoke, Jegede and Oyebanji (1997) used a sample of 248 secondary school students in two classes selected from two schools, to investigate whether the teaching of selected biological concepts using analogical linkages chosen from the learners' socio-cultural environment would significantly reduce the achievement differences in selected biological concepts between females and males. They found out that boys and girls benefited significantly from teaching with environmental analogies when compared with their counterparts who were not taught using such analogies. Also, the use of environmental analogies seemed to have produced equivalent performance in the attainment of biological concepts for both males and females in the experimental group. While these studies have implications for teaching and learning in science, more research is needed in this area to corroborate these findings.

There is a dearth of studies on classroom life in Botswana. The few studies that are available tend to paint a dismal picture of what is going on in science classrooms in Botswana. Rowell and Prophet (1990) in a study aimed at portraying the daily realities of classroom life in Botswana used classroom observations and informal discussions as sources of data. Unlike earlier studies reported here which made use of observation schedules, the researchers in this study did not pre-determine any specific attributes of the classroom. They treated interactions in the classroom as episodes whose meaning and complexity may be compromised by breakdown. They conclude among other things, that (i) the question and answer strategies are very commonly used particularly at the beginning and end of the lessons. In these exchanges, teachers seem to expect and to be satisfied with brief responses at low levels of cognitive functioning, (ii) the students are perceived as passive recipients of teacher transmitted knowledge and (iii) perhaps as a result of the problems of instruction in a second language teachers tend to over simplify the content to such a level that it is stripped of all the important concepts leaving only a few essential terms for definitions, memorisation and recall. While this study provides "thick descriptions" of lives in the classrooms, it falls short of elucidating the metaphors and beliefs teachers hold about the teaching-learning process which actually inform and direct teacher behaviours in science classrooms. The study also seems to portray students as "seen and not heard" in informing interactions in the classrooms. In a sense, how do students belief they should be taught? The data were collected solely by the investigators, which leaves the study suspect of experimenter bias, reflecting more of the western mechanistic expectations of teacher and pupil behaviour totally devoid of the anthropomorphic nature of the Botswana society.

In another study, Prophet and Rowell (1993) used a convenience sample of five junior secondary schools in and around Gaborone. They found that (i) teachers out-talk their students, (ii) they completely ignore student's responses with an occasional acknowledgement of the correct responses, (iii) teachers place a lot of emphasis on the elite language too often at the expense of concept development, and (iv) the students tend to respond to the questions in a random manner and that guessing seems to be the order of the lesson. It is suggested that the study seems to pay very little attention to the role of peers in the learning situation and the interactions between students. The emphasis seems to be placed on the interaction between the teacher and the students. As a result, the study does not seem to shed any light on the students' and teachers' interpretations of the observed interaction patterns. As such it falls short of elucidating the reasons why teachers do what the do in their classrooms.

Yoder et.al. (1994) in a comparative study to explore student-teachers' perceptions of what constitutes a "good teacher" in Botswana, California, Finland and Zimbabwe, conclude that in Botswana, the respondents placed a significantly greater emphasis on instructional skills than on the personal characteristics (warmth, friendliness, relating well etc.) of the teacher.

This study recognises the role that qualitative studies play in further elucidating the interaction behaviours of teachers and students in science lessons. Hence, the present study employed a phenomenological viewpoint based on the social interaction approach to curriculum development.

2.9.2.3 Summary.

In this chapter, the evolution of constructivism was traced. Theories of learning that have a bearing on the development of constructivism were discussed and their strengths and weaknesses with respect to exemplary practice were highlighted.

A view of contemporary constructivism, as a multi- faceted concept was presented and some versions of constructivism viz; radical, trivial, contextual and social constructivism were discussed. The chapter concluded by citing a number of studies that could be considered to provide the appropriate context for the presented study.

CHAPTER THREE

3.0.0 Methodology.

3.1.0 Introduction.

This study sought to determine the effects of exemplary teaching and learning materials on the students' participation and achievement in biology in Botswana science classrooms. In particular, it was concerned with examining the effects of student-teacher-material interactions on the students' participation and achievement in biology.

Sharrock and Anderson (1993) endorse the view that most classrooms are generally characterised by teacher talk and that to understand teaching one must look at the issue of verbal interaction. Perhaps this explains why the common form of classroom research today is thronged with vignettes extracted from an overwhelming stream of utterances. Often, this entails the coding of utterances according to some category system (Furlong and Edwards, 1993; Walker and Adelmen, 1993; McIntyre and Macleod, 1993). Systematic observation was at one time a dominant research paradigm in the social and educational research. A review of studies in this area however, indicates a resurgence of more qualitative or naturalistic inquiries into classroom interactions (e.g. Tobin and Garnett, 1988; Prophet and Rowell, 1993; Fuller and Snyder, 1991; Hilsdon, 1993,1996).

The tension between research studies employing systematic coding schemes and those using naturalistic inquiries cannot just be wished away. It is a fundamental tension between the positivist, behavioural frameworks and the interactionist paradigms (Delamont and Hamilton, 1993). In the former, provision of appropriate stimuli will result in a response. In this sense, the old adage that one may take the horse to the water but cannot make it drink does not seem to hold. All that is required is to provide the appropriate conditional stimulus and the proverbial horse would drink. However, using pre-specified coding categories tends to reduce the complex and dynamic classroom life into fragments of predictable behaviours. The interactionist (or presently constructive paradigms) surfaced from the writings of Herbert Blumer in the 1940's. He viewed human actions as active constructions emanating from complex processes of interpretation through which people make sense of the world around them (Hammersley, 1993). These processes of interpretation derive and also inform perceptions which are formed in the course of social interaction. Of course, the work of Piaget and associates from the earlier to the middle part of this century is noteworthy in this regard.

Quantitative research designs tend to be more structured and prescriptive than qualitative ones. The main aim of quantitative research is to test hypotheses, show relationships between/among variables, predict phenomena, establish facts and statistically describe phenomena. The data from such studies are often described as hard, dry, empirical, or statistical (Bogden and Biklen, 1992). The data are by and large, expressed as numbers and interpretations are made in terms of comparisons and partitioning of those numbers (Wiersma, 1995). It is this trait of quantitative research that makes systematic observation an appealing component of positivist studies. The structuring and the use of pre-specified coding categories however, have inherent problems with the data collected and these problems will be discussed later in this chapter. The sample size is ordinarily large and randomly selected. Extraneous factors are carefully controlled and control groups are used to establish the effect of the treatment. Research questions are formulated by operationalizing variables.

Qualitative research designs on the other hand are generally less structured and more flexible than those in quantitative studies. Wiersma (1995: 211 - 212) notes certain underlying assumptions about the epistemology of qualitative research designs. Among these are: (i) phenomena should be viewed holistically, and complex phenomena cannot be reduced to a few factors or partitioned into independent parts; (ii) since the researcher is operating in a natural setting, as much as it is possible, openness should be maintained about what should be observed to reduce the chances of missing out on something important and (iii) post-hoc conclusions should be the priority instead of *a priori* assumptions and conclusions.

Central to many qualitative studies is a framework that focuses upon participant perspectives. Accordingly, human behaviour, is perceived as a product of social interaction and that could only be understood in terms of the social processes, meanings, metaphors, definitions, descriptions, symbols, and processes of interpretation which produce such actions (Berg, 1982; Burgess, 1985; Bogden and Biklen, 1992; Hammersley, 1993)

According to Berg (1989), qualitative researchers are interested in the way humans arrange themselves in their settings and the sense they make of their environment through symbols, rituals, social structures, social roles and so forth. Qualitative studies primarily seek to develop sensitising concepts, describe multiple realities and develop understanding. The data are often described as "soft", "thick" rich and deep in describing people, situations, and conversations. The research questions are designed to explore issues in all their complexity other than being framed by operationalizing variables (Blumer, 1969; McCall and Simmons, 1969; Hammersley, 1963; Berg, 1989; Bogden and Biklen, 1992).

3.2.0. Research Background.

A review of studies on life in the classroom reveal that researchers tend to differ in their focus, approaches to data collection and the nature of data collected. Furlong and Edwards (1993) suggest that the facts that the researchers record and the interpretations they make of such facts are to a large extent a product of the theoretical assumptions they make regarding data.

Research in education has for a long time been dominated by the talk of indicators, variables, and measurements, by the use of surveys and quantitative techniques (Burgess, 1985). More recently, there has been a resurgence of studies that allow researchers to have insight of the understandings and perceptions of others and to explore the way people structure and make sense of their daily experiences.

For a long time now, qualitative and quantitative approaches have been considered and used in isolation of each other. Burgess (1985) argues that such an approach is very parochial and places an undue straight jacket on research. The social world is complex. It is vital then that consideration should be given to the methods that are appropriate for the particular research problems. It is also important to consider how different research techniques could be used alongside each other or even be integrated to yield meaningful research data (Seiber, 1973; Burgess, 1985).

An eclectic approach in educational settings where the researcher has a flexible research design, is willing and able to utilise a wide range of methodologies can bring distinct advantages to the research project. This is even more important in that there is no single way of exploring educational phenomena that is inherently superior to others in all research contexts (Burgess, 1985; Cooley and Bickel, 1986).

The method adopted for this study was an eclectic approach in which both qualitative and quantitative approaches were used to complement each other. As Mills (1959) and Berg (1989) argue, studying humans in a symbolically reduced, statistically reduced fashion, posits a danger that conclusions which may be arithmetically precise, may not fit reality.

Teaching and learning are characterised by great complexity. There seems to be a general lack of understanding about this complexity given the nature and state of research in this area. To understand this complexity perhaps, it is vital to establish relationships between factors that are central to understanding such phenomena. Hence, quantitative approaches have been used in this study to explore relationships between/amongst variables. Other aspects of this study include: the patterns of verbal and non-verbal interactions exhibited by teachers and students exposed to exemplary teaching; the relationship between the student's sex and academic ability; the level of participation and achievement in biology lessons emphasising exemplary practice and the effects of co-operative, competitive and individualistic laboratory interaction models on student's participation and achievement. While correlation of these variables might reveal the nature of the relationships, it might be inadequate in accounting for the social processes that resulted in such relationships. To work from a social perspective in order to understand these social processes and meanings participants attach to phenomena, a qualitative approach based on social interactionism was adopted.

3.2.1. Symbolic Interactionism

Symbolic Interactionism accounts for both the symbolic and the interactive as experienced and organised in day to day activities of social groups. As Plumer (1991:ix) suggests, it explores

> ...how meanings emerge, are negotiated, stabilised and transformed; at how people do things together through joint actions; and at all levels of collective life.

Symbolic interaction can be used as a concept that embraces a variety of related theoretical perspectives. Central to all this is the attention paid to the subjective understandings. Human actions are a product of how they interpret the social world around them. As a result, symbolic interactionists are primarily concerned with the *nature of interaction*, that is, on the dynamic activities characterising interaction between individuals as opposed to the effects of social structure or social situation on the individual's behaviour (Cohen and Manion, 1989). In this sense, human behaviour, from an interactionist perspective is not a biological instinct, but a product of learning (Berg, 1989). Meaning does not emanate from the intrinsic makeup of a thing; neither does it come from the psychological elements between people. The meaning of a thing emanates from "the ways in which other persons act toward the person with regard to the thing" (Berg, 1989). Meaning then becomes a product of social interaction. It derives from the social processes of interacting individuals. Meanings, therefore, are constructed as one interacts with the environment and what constitutes that meaning is an interpretation of the sensory world. Studies that adopt symbolic interactionism as a theoretical perspective tend to focus on these meanings and perspectives that participants attach to situations (Burgess, 1985; Berg, 1989).

It has been pointed out earlier that most of what goes on in classrooms is talk. To understand learning and teaching, therefore, one needs to understand the nature and meaning of talking in classrooms. Hustler and Payne (1985) ague that talk gives symbolic interactionists access to the meanings and interaction patterns of their participants.

3.2.1.1 Participant observation strategies

One of the strategies closely associated with qualitative research studies is participant observation. According to McCall and Simmons (1969:28), participant observation is "not a single method, but a type of research enterprise, a style of combining several methods toward a particular end." The main aim of participant observation is to produce an analytic description of a complex social setting.

Gold (1969) distinguishes between four levels of involvement in participant observation. These include (i) complete participation (ii) participant-as-observer (iii) observer-as-participant and (iv) complete observer. In all these cases, the researcher's aim is to gain a deep and prolonged contact with the life situation and a systemic, encompassing and integrated feel of the context being studied (Wolcott, 1992).

In complete participation, the identity and purpose of the researcher are not revealed to those who are being studied. The observer interacts with the participants as naturally as possible in whatever areas of their lives he/she is interested in and are accessible to him/her to successfully role play. The researcher is basically pretending roles and it matters to him/her to successfully play those roles.

The participant-as-observer situation differs from complete observation in that both the researcher and the participant are aware that theirs is a field relationship. The researcher spends more time with the participants developing the relationship. The researched benefit in that the researcher is quite prepared to participate more than to observe, as in teaching classes when teachers suddenly cannot make it. In some cases the researcher would do some formal observations and in others informal observations as in staff-rooms and preparation rooms.

The observer-as-participant situation is characteristic of studies that involve one visit interviews. It involves formal observations and the contact with the participants is very brief compared to complete participation and participant as observer relationships. For this reason, there is a risk of misinterpretation of the activities of the participant and of the participant misunderstanding the researcher.

When the researcher is a complete observer, he/she is completely isolated from any form of social interaction with the participants. Like in the complete participant, the participants are not aware that they are serving as informants to the researcher. The researcher approaches the participants and observes them in such ways that do not attract any attention to himself/herself. This lack of social interaction with the participants reduces the chances of "going naive" as it could be the case with complete participant but carries a real threat of ethnocentrism; a situation whereby lack of meaningful interaction with the participants leads the researcher to seemingly or actually reject the views of participants without due apprehension of such views (Good, 1969).

The role adopted in this study was that of participant-as-observer. The teacher was made aware of the nature of the study and what his/ her role in the research study would be. The students as well were made aware that someone (visitor) would be sitting in their lessons and writing down some observations about what they were doing and that during their lessons, they were free to work with him/her in their groups and to ask questions about what they were doing. They were also told that he/she would be helping them in their practical and that should they require any assistance then they should just call him/her as much as they could call the teacher. But should the "visitor" - also "a student", and the class experience some difficulty they could call the teacher. He/she would stand in for the teacher when he/she could not make it. He/she would help prepare reagents and get apparatus ready, distribute equipment and help clear up the laboratory at the end of the lesson.

3.2.1.2 Ethnography

Ethnography both as a word and a concept has been around for a very long time. It is one form of qualitative inquiry and as Berg (1989) points out, it has become an extremely effective research technique. It is a qualitative research strategy that includes a plethora of strategies like "participant observation, formal and informal interviewing, document collecting, filming, recording, and so on" (Van Maanen, 1982:103).

Ethnography as a research method, gives the researchers a vantage to understanding people's ideas, belief systems, perceptions, values, meanings, contexts and assumptions or what is termed the "native point of view" (Berg, 1989; Hammersley, 1993; Ogbu, et. al., 1994). It attempts at describing and interpreting processes of interpretation in a social setting (Berg, 1989). Attention is given to describing local peculiarities, individual perspectives and interpretation of the world around them (Miles and Huberman, 1994).

Since providing rich, thick and deep descriptive data is an important aspect of ethnography, the researcher needs to spend prolonged spells of time in face-to-face contacts with the participants (Miles and Huberman, 1994). He/she also needs to participate in their day to day activities in order to gain an in-depth and contextualised understanding of their views (Sills, 1968; Ogbu, et. al., 1994). According to Hammersley (1993), ethnography like interactionism, emphasises that human actions can only be understood within the context of the processes of interpretation that generate them. In contrast, however, where interactionists regard meaning embedded in action as emanating from relatively stable perspectives commonly portrayed by a social group, ethnographers see meaning as depending on the context under which the actions take place.

Ethnography as a tool to explore and document peoples' understandings of phenomena, has been used in a variety of ways by researchers (Spradley, 1979; Berg, 1989; Ellen, 1984). One unifying theme about these conceptions of ethnography is that it is a research method that places the researcher amidst the phenomena to be researched since it requires the researcher to reside with the participants and to understand their language (Sills, 1968; Delamont and Hamilton, 1984, 1993; Berg, 1989; Ogbu, Sato and Kim, 1994).

Ogbu, at. al. (1994) suggest four features that are characteristic of ethnography. These include (i) contact and interaction with the researched group for an extended period of time, (ii) proficiency in the native language, (iii) trying to see things from the point of view of the participants (empathy), and (iv) a holistic perspective with which relationships between observed data and other relevant data and ideas are viewed and the ability to discern the relevance and importance of such relationships.

In conducting an ethnographic study, it is important to establish a healthy working relationship and gain trust of the researched in order that valid and reliable information could be accessed. McCall and Simmons (1969) suggest that rapport goes beyond being just a technique to gain access to a group but it involves also the sensitive understanding of individuals which would aid an insightful analysis of behaviour. It is also important that manipulation of variables is minimised and greater reflexivity is attained (Hammersley and Atkinson, 1983; Ogbu, et. al., 1994).

Berg (1989) distinguishes in two major ways, between micro- and macro-ethnography. While the former is concerned with specific aspects of the phenomena to be studied, the latter focuses on everything that constitutes the life of a group. Micro-ethnography also explores face-to-face interactions of a group to make sense of the perceptions of the participants.

Sanday (1979) and Ogbu, Sato and Kim (1994) suggest three paradigms of ethnography. Holistic ethnography is concerned with examination of language, belief systems, ideas and artefacts. This could be viewed to be synonymous with what Berg (1989) refers to as macro-ethnography. Semiotic ethnography has to do with language and ideas while behaviourist ethnography concerns itself with behavioural interactions. Perhaps, the difference amongst all these is more of a linguistic nature since basic to all of them is the overarching concern to explore aspects of social life in communities from the view point of the members of those communities.

To explore classroom life in Botswana biology lessons, a holistic approach used alongside a variety of micro-ethnographies was employed to unravel the complex social aspects of teaching and learning. The approach is holistic in the sense that general classroom ecologies were studied including verbal and non-verbal interactions among students and between students and the teacher as well as the notion of dominance and how membership of a group affected the actions of individuals. A variety of micro-ethnographies were intended at discourse analysis in order to understand the process of interpretation and sense making involved in the utterances within small groups.

3.2.2 Small group work

Human behaviour tends to differ depending on whether one is acting within a group or as an individual. The group atmosphere tends to provide opportunities for one to negotiate and play different roles in the group. In a sense, the group environment has an effect on the actions and meanings attached to those actions by members of the social group.

Meanings as argued earlier, are a social construct. Learning is in part an interpretation and negotiation of meanings. The group environment therefore, provides a vehicle for group members to negotiate and construct their ideas. In this interactive negotiation of meanings, the learner has an influence on the group just as much as the group has on the learner. As Foster (1989) puts it, it is in the groups that personalities are formed. It is again here in the group setting that one learns to contribute to the group verbal or non-verbal, conscious or non-conscious behaviours. The group setting also affords one an opportunity to learn to contribute and receive ideas, to defend his/her ideas and to accept and go along with other people's ideas. According to Webb (1985), small groups are effective in increasing verbal interaction among students. Linn and Barbules (1993) argue that groups are effective for brainstorming and generating ideas. They also benefit students in that they foster cognitive skills, promote social skills and impart work place skills. The group setting offers a battleground on which one strives for roles, intellectual status and recognition. In this sense, the Gestalt of the group is uniquely its own and is greater than the sum of its individual members (Burns, 1989; Robson, 1989).

Certain features of the group have been found to have an effect on the dynamics of the group. The extent and level of participation of group members have been found to be influenced significantly by things like its size, seating arrangement, and task specialisation among members. Also significant are the duration and frequency of the group meetings and also the presence or not of an observer (Burns, 1989; Robson, 1989). There is a general consensus among researchers that in general a small group of about five people is optimum and allows for adequate participation and higher levels of consensus during group discussions (Robson, 1989).

Group work as a tool to enhance participation in science lessons was adopted in this study. The group sizes did not exceed six members. Students were randomly and arbitrarily assigned to groups and were allowed to choose their leader and secretary for every practical activity they were assigned. The secretary would record the consensus of the group over the issues under investigation and report to the class during the time for reporting. The students were also allowed to each identify parts of the practical activity they wanted to carry out for the group.

3.2.3 Social interaction: a tool for curriculum development.

A concern for poor performance by students in the science-based subjects is a long-standing concern for the Government of Botswana. It is observed that

> Despite adequate provision of facilities and resources for the teaching of science, the system still does not produce enough students with the necessary qualifications to pursue science-based programmes at the University level (Republic of Botswana, 1993).

This may suggest that availability of resources and facilities is only a part of the necessary conditions for meaningful learning to occur. From a constructivist perspective, meaningful learning occurs when the learner engages with the learning situation to construct a valid understanding of the phenomena in question. Teaching, therefore, should be concerned with creating and providing conditions under which students would meaningfully interact with the learning situation.

The science curriculum in Botswana is learner centred. Studies focusing on lives in classrooms, however, tend to show that this is not necessarily what one finds going on in science classrooms. Some researchers suggest that this could be due to the fact that the curriculum is irrelevant to the needs of the students while others suggest that the contexts under which teachers are to implement such curriculum innovations are not conducive to such an endeavour. The metaphor "tissue rejection" has been used to describe a situation where the existing educational ecology does not allow for effective implementation of a new curriculum innovation. Tissue rejection from a biological perspective is a condition where the body rejects a tissue because the immunological condition of the body is not compatible with that of the implanted tissue. When this happens, the new tissue is not able to become a viable part of the body. Similarly, innovations in science education that do not take into account the classroom eco-culture may suffer the same fate of rejection.

Beyond the classroom eco-culture, teachers and students alike bring into the learning situation their own ideas about teaching and learning. For instance, the way teachers structure and execute their teaching is heavily influenced by their prior ideas about teaching. A new innovation in teaching is likely to bring with it ideas and practices that are at dissonance with those of the teachers. When this happens, the teacher is likely to feel alienated, incompetent and vulnerable to failure; a situation described by Tobin (1996) as symbolic violence.

To circumvent the problems of tissue rejection and symbolic violence the curriculum to be used in this study, was developed in co-operation and consultation with the teachers. This was in recognition of the fact that schools are not culture neutral. They are sites where norms are observed, and as such are "contested cultural sites, not simply places where instruction takes place and bits of neutral knowledge are transferred" (Giroux, 1991:181).

Ten experienced biology teachers were involved in identifying the topic that could be developed for exemplary practice as well as in validating the materials that were produced. They also responded to the exploratory questionnaire on the traits of an exemplary biology teacher that formed the basis for the development of the exemplary package. The teachers also trial tested the materials and commented on their suitability for their classrooms.

3.2.3.1 Reflective practice: mirrors of classroom interaction.

Creating a conducive environment for learners to construct their own knowledge requires not only the pedagogical knowledge from the teacher, but also a working knowledge of what is happening in the classroom as opposed to what ought to happen. Providing teachers with mirrors of their actions therefore, became the central concern of this study. This provides the teachers with adequate knowledge of the nature of interactions prevalent in their classrooms to make informed decisions about what constitutes reality from rhetoric. Hopefully, teachers with this knowledge would be in a position to select and use teaching strategies that are capable of fostering meaningful learning. As Bartolome (1994:180) rightfully notes:

> ...teaching strategies are neither designed nor implemented in a vacuum. Design, selection and use of particular teaching approaches and strategies arise from perceptions about teaching and learning.

It appears then, that to explore the teaching approaches that one observes in the classrooms, it is important to understand how the teachers perceive the processes of teaching and learning. To understand these perceptions, it is necessary for the researcher to negotiate meanings with the teachers and to provide mirrors for their actions. It was intended through this process to provide teachers with opportunities to

> ...look at themselves...to turn their attention to what *actually* goes on in schools rather than to be so singularly pre-occupied with what *ought* to go on in them. (Wolcott, 1982:7)

Schön (1988) refers to this as instructional supervision of teachers and views it as including any such activity that supports, guides or encourages teachers to be reflective in their teaching.

Coaching reflective teachers was a challenge in the sense that the teachers who volunteered to participate in this study were experienced teachers who had already established ideas about teaching and learning. They had been in the system and have learnt to cope and survive the stress and strain of teaching. For them to teach using the exemplary materials, they had to appreciate the content and the proposed pedagogy. For this to happen, teachers needed to be "given reason". This involved some sort of coaching where the researcher and the teacher had to negotiate meanings, roles and ideas. As Tobin (1993:218) points out:

> ...the beliefs, metaphors, and metonymic models of teachers and students are associated with curricula actions. To change the curriculum, therefore, it is necessary for teachers and students to reconceptualise the manner in which they make sense of their salient roles.

Schön (1988:23) points out three things involved in coaching reflective teaching. These are: i) conceptualising and responding to the substantive issue of learning and teaching in the situation at hand, ii) entering the teachers ways of thinking about it; particularising one's description or demonstration to one's sense of the teacher's understanding and iii) doing things in such a way as to make defensiveness less likely.

The basic principle transcending the process of teacher training here is what Elliott (1993) describes as the hermeneutic view of teacher education as opposed to the rationalist and the social market views of teacher education. In the rationalist view, good practice is perceived as the result of consciously applying a theory, and as deriving from theory. In the social market view, the results of good practice are perceived as quantifiable products, which can be pre-specified, in tangible and concrete form. In which sense the learning outcomes are construed as behavioural. From a hermeneutic perspective however, good practice does not derive from theory nor is theory reducible to practice. Rather, good practice derives from interpretations of particular situations as a whole and to improve practice, one has to improve the interpretations as well. The role of theory in improving situational understanding is not denied, but it is subservient to the latter. Behaviour therefore, is dependent on the situational understanding. How one would respond in a practical situation cannot be specified in advance. This means that, good practice is not so much about drill and practice, but about interacting with the situation and responding wisely and intelligently as the situation presents itself. It takes discernment, creativity and flashes of insight to do this. It is about grasping the meaning of the situation and responding accordingly.

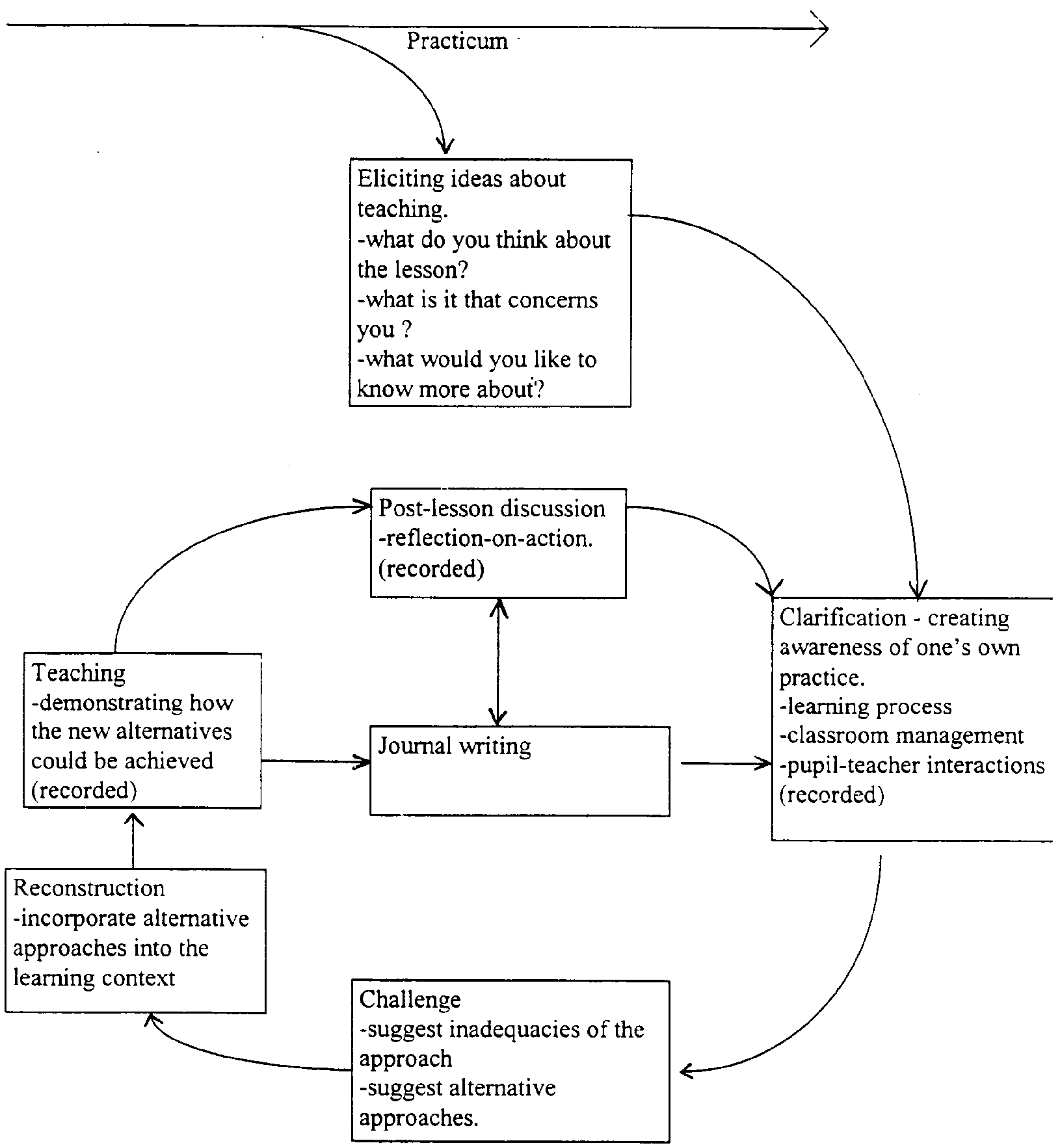
The approach to instructional supervision adopted in this study was based on what Schön (1988:22) refers to as a "Hall of mirrors". In this situation,

> ...a coach helps, provokes, and encourages a teacher to reflect her own practice. A coach supports her reflection on her own reflection-in-action: that is, her effort to make explicit to herself what she is seeing, how she interprets it, and how she might test and act on her interpretation.

To achieve this, teachers went through a practicum in which they could explore and reflect on their practice. A two-day workshop in which teachers went through a seven-stage cycle to help them enter a reflective discourse with issues at stake in their practice was conducted. Grimmet et.al.(1987) identified three major conceptual approaches on research on reflection. They contend that these are primarily based on i) what is the subject of reflection, ii) the way the process of reflection is carried out, and iii) what reflection purports to achieve. This study is much inclined to the latter where the conceptual orientation is more to do with the purpose of reflection. Issuing from this, the practicum portrayed reflection as a means for reconstructing experience.

In this scenario therefore, teachers were helped to acquire knowledge that could assist them apprehend and transform practice (Zeichner, 1994).

Figure 1: Organisational structure of the induction workshop.



Stage one involves elicitation of ideas about teaching and learning. To create a template on which teachers would reflect their ideas against, a video of a pre-recorded normal lesson was shown and teachers had to raise their concerns about the lesson and what things about the lesson they would want to know more about. Teachers' ideas form an important tool to analysing their beliefs about teaching and learning. These are also useful in informing the reflective discourse between the coach and the teacher.

The second stage is the clarification stage. This stage is meant to create awareness of one's own practice. The teachers were clarifying the teacher actions and accounting for such actions, that is, trying to explain why the teacher was doing what he/she did in terms of the learning process, classroom management, and teacher-student interactions. This also included aspects of the context under which the lesson was taught.

Stage three is the challenge stage where teachers' ideas and beliefs are challenged. The intention of this stage is to perturb the teachers' taken-for-granted beliefs and practices. Shaw and Etchberger (1993) equate the principle of perturbation with Newton's first Law of motion, which states that "A body at rest or in uniform motion will remain at rest or in uniform motion unless some external force is applied to it". In the same tone, teachers are likely to continue teaching the same way unless something or someone challenges their ideas, belief systems or their practices.

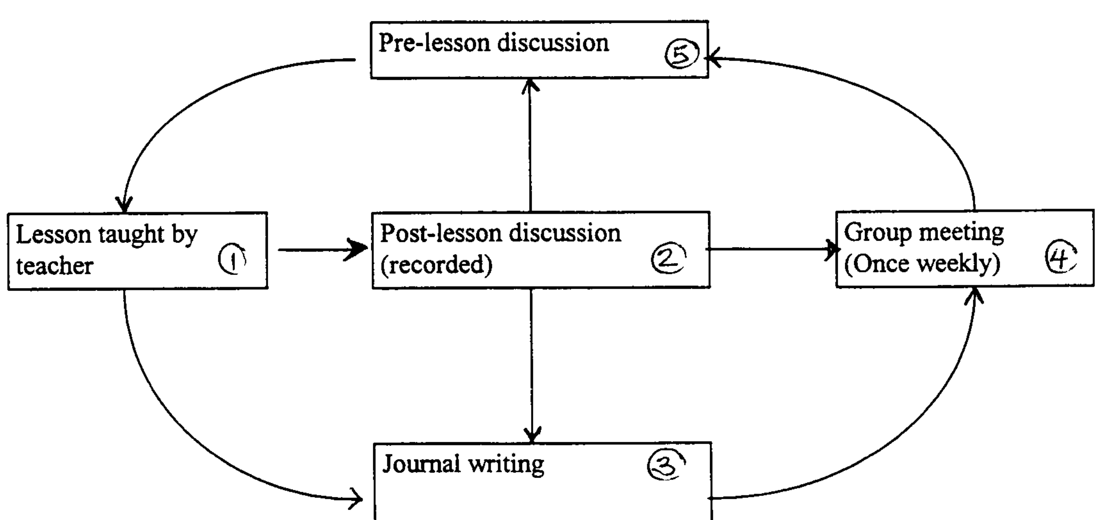
At this stage, teachers would suggest inadequacies in the teaching approach in question and in the light of the ensuing debate, suggest alternative strategies. It was crucial at this stage that the coach makes sense of the issues in question from the teacher's point of view. It is when the coach and the teacher share the meanings of the teacher's experiences, that they can jointly establish the logic and the rigour of the teacher's on-the-spot experimentation. On the other hand, the coach is well placed to provide an environment that will help the teacher not to be defensive. It is at this stage that the teacher is open to confusion, to not-knowing, to vulnerability and hence to defensive strategies which tend to be a natural reaction to protect oneself from vulnerability (Schön, 1988).

The fourth stage is that of reconstruction. This is a stage where the teacher incorporates the alternative strategies into the learning context to build an epistemology that is particularly his own (Clarke, 1994). It is also the stage where the teacher portrays what in the context of exemplary practice, is realistic and worth the trying within the given teaching and learning context.

Stage five is the teaching stage where the teacher tries out the reconstructed teaching strategy. It is during this time that the teacher reflects-in-action as he/she experiments with the new teaching strategy. Stage six is the post-lesson discussion between the teacher and the coach. At this time, the coach helps the teacher reason through some of the issues at stake concerning the lesson. The coach even at this stage is engaged in the process of sense making and as such tries to see and hear things from the point of view of the teacher so as to best help the teacher reflect on the interaction patterns observed during the lesson. The last stage is the journal writing stage and it involves the teacher keeping a journal of his/her experiences when teaching using the exemplary materials. Laboskey (1994) suggests that journal writing is recommended because it is a way of keeping track of experience, can be referred to at a later stage and hence helps improve the power of memory alone. It also helps the teachers to evaluate their ideas as they write. This increases their awareness of the teaching process they are involved in.

Since there was not enough funds to keep the teachers in a workshop for two weeks, and the teachers themselves were not prepared to stay that long, the two day workshop was followed by training in-situ at the schools. Each teacher was seen at least twice every other week for a period of one month. During these meetings, the teachers went through a reflective cycle to enable them to reflect on their actions in the classroom.

Figure 2: Weekly reflective cycle for teachers.



Stage one in this cycle involves the teacher teaching one of the lessons that is video recorded. The teacher then enters the post-lesson discussion with the researcher. The purpose of this is to allow the teacher and the coach to reflect-on-action and negotiate meanings of the observed interaction patterns. The third stage involves the teacher writing his/her journal to keep a record of the experiences in the classroom. The fourth stage is the pre-lesson discussion as the teacher goes to teach the next lesson. In this discussion, the teacher refers to the journal and the post-lesson discussion notes to bring forward some of the issues at stake that would need to be attended to in the forth coming lesson. The last stage is a group discussion involving the two teachers using the same teaching strategy and the researcher. In this case the researcher would bring the teachers to a central point and the team would discuss the issues that concern them in that meeting. This served both a reconstructive and a motivational purpose since teachers could as a team, map out ways of addressing some of the common problems they were facing.

3.3.0 Research Methods

As stated earlier, the concept of exemplary teaching does not as such mean something outstanding and flawless. It refers to a proto-type teaching approach that is perceived, within the context in which it is used, to produce the desired results and hence, worthy of emulating in related contexts. Starting from this premise then, a curriculum package was developed to be used to guide exemplary teaching.

The curriculum package consisted of the student's workbook, scheme of work, teacher's guide, lesson plans, and an achievement test. The workbook was intended for use by the pupils. It contained instructions on how pupils had to carry out certain experiments. Since the study was rooted on a constructivist epistemology, the workbook was structured such that the students would construct their own knowledge through collaborative work involving group discussions, presenting information in oral and written form, describing phenomena and relating everyday experiences to issues at stake during the lesson. The questions used throughout the workbook required the students to reflect on the content and the processes encountered.

The curriculum package contained fifteen lessons, each lasting for two periods (i.e. 35-40 minutes). The lesson content was structured so that the students are central in the learning process. They were to do the experiments and demonstrations while the teacher served a facilitative role. The materials were arranged such that each student had ample opportunities to participate in group discussions and presentations. Also, the students were allowed to talk or write their viewpoints while performing the assigned tasks. This served on the one hand to further reduce the authority of the teacher in deciding what was worthwhile knowledge while on the other it increased the pupils' leverage in sharing their ideas in small groups and in reaching consensus in group or whole class discussions (Wheatley, 1991).

The lesson plans gave a comprehensive guidance to the teacher concerning the materials and equipment needed, the group sizes, the way to divide the students, the tasks students should do and the way to assign students' tasks and the approximate time activities were expected to last. In keeping with the notion of reflection inherent in the study, the workbooks and the lesson plans allowed for teacher and student reflexivity, creativity and intuition.

3.3.1 The sample and sampling procedure.

At the stage of this study, form three (grade 10) was the first year of a three-year Cambridge Ordinary-Level School Certificate (COSC). Twenty-seven senior secondary schools in the country which offer COSC constituted the population studied. The sample was drawn from the 27 schools. The sample for the pilot study, however, was picked from a cluster of five schools in the Serowe/Palapye area, i.e. the central region of the country. These were: Swaneng Hill, Lotsane, Moeng, Madiba, and Letlhakane senior secondary schools. Out of these, Lotsane, Swaneng and Madiba senior secondary schools were picked at random by picking the names from a bag and assigned to the co-operative, individualistic and competitive treatment groups respectively.

The teachers in these schools who were going to teach using exemplary materials had to satisfy four conditions: i) they had to be recommended by the head master, the head of department and students as an outstanding science teacher; ii) they had to have at least two form three classes that they were currently teaching; iii) they had to be willing to teach using the exemplary materials and iv) they had to be willing to undergo the training session. Each teacher in the treatment group used the exemplary materials and teaching strategies on two classes. This involved a total of three teachers and 246 students.

To minimise the effects of contamination among treatment groups, the sample for the main study was equally stratified. It was picked among clusters of schools in Francistown, Gaborone and Lobatse areas, i.e., the southern and the northern regions of the country. The co-operative treatment group was made up of two schools picked randomly out of a group of four schools in the Francistown area; the competitive was similarly picked from a cluster of four schools in the Lobatse area and the individualistic group was picked from five schools in and around Gaborone. The individualistic treatment group was left to schools near Gaborone so that should they run short of materials and equipment, they could easily borrow such from the University. In each of the two schools in the treatment groups, one teacher who had two form three classes was chosen. One of the classes would sit the pre-test while the other class acted as a control for test-wiseness and did not sit the pre-test. A total of seven teachers and 446 students were involved for the main study.

3.3.2 Sources of data.

To place this section in context, it is important to reiterate the aim of this study. The study sought to explore the effects of exemplary teaching and learning materials on students' participation and achievement in biology. More specifically, the study was concerned with determining the effects of student-teacher-material interactions on the students' participation and achievement in biology. To fully appreciate the depth and complexity of this interactive classroom life, a variety of data sources were accessed to provide meaningful information about classroom life. The data sources included participant observations in which classroom observation schedules were used. These observations were alternated with field notes. In the latter, the researcher would come into the class with no pre-specified tasks to observe but to record classroom activities as holistic episodes. Formal and informal interviews, group interviews, survey questionnaires and achievement tests were also part of the sources of data.

3.3.3 Types of data.

Consonant with an eclectic nature of the study, both qualitative and quantitative data were collected. Though the study leaned more to the qualitative interpretive approach, quantitative data were also collected at the micro-level of instruction. The classroom observation schedule, biology achievement test, and survey questionnaires were used to collect quantitative data while the teachers and student interviews and participant observation provided the qualitative data.

3.3.4 Instrumentation

To explore exemplary practice in biology classrooms in Botswana, a total of ten research instruments were produced and used to collect data in this study. Four of these focused on quantitative data while six were used to collect qualitative data. The quantitative data gathering instruments included the Exploratory questionnaire on the traits of exemplary teachers, the Biology laboratory interaction schedule, the Biology achievement test and the Student participation inventory while the qualitative data gathering instruments included the semi-structured teacher and student questionnaires, the semi-structured teacher and student interview schedules and the student's actual and preferred classroom environment inventories.

The Biology Laboratory Interaction Schedule is a modified version of Flanders' interaction categories adapted for use in Botswana schools. In adapting it, special attention was paid to the criticisms labelled against science teachers in the country. These include the fact that teachers do not take student's ideas aboard when they plan and teach their lessons, they tend to ignore students' incorrect responses, do not challenge students' responses to encourage logical thought and that teachers out talk their students (Prophet, 1990; Prophet and Rowell, 1990; Fuller and Snyder, 1991; Rammiki, 1991; Ogunniyi and Ramorogo, 1994).

3.3.4.1 The Biology Laboratory Interaction Schedule (BLIOS).

The Biology Laboratory Interactions Observation Schedule (BLIOS) contained eighteen categories. A section of it dealing with teacher behaviours consisted of twelve categories, three of which had to deal specifically with the criticisms levelled against science teachers. Six categories dealt with student behaviours.

One of the serious shortcomings of systematic observation, of which BLIOS is representative, is that: (i) the data that are collected are mainly data that can be captured into the pre-specified categories. Qualitative data that may be useful in creating a more comprehensive picture of classroom life is often ignored, obscured and distorted because the instruments are crude, ill-defined and insensitive to such data (Simon and Boyer, 1974; Delamont and Hamilton, 1984, 1993) (ii) they tend to concentrate on small bits of information rather than a holistic approach to the concepts under investigation and iii) they deny the observer reflexivity so necessary to the observer in a complex teaching and learning situation (Delamont and Hamilton, 1984, 1993).

To address this problem at least in part, BLIOS contained a section that dealt with more qualitative aspects of the lesson. A seventeen item, five point Likert scale format was developed to collect data dealing with other aspects of the lesson not directly addressed by the observation schedule. It addressed issues of lesson presentation (planning, mastery of subject matter, use of chalkboard, appropriate use of teaching strategies), classroom management (efficiency, order and control), class interactions (student participation, learning environment, small group work and discussions) and the personal traits of the teacher (sensitivity to individual differences, communication skills and self presentation).

3.3.4.2 The Exploratory Questionnaire on the Traits of an Exemplary Teacher (EQTET).

In an attempt to move away from the rhetoric of classroom practice and to place the notion of exemplary practice on an interpretive perspective, the teachers were involved in developing the concept of exemplary teaching and learning. It was particularly important to involve the teachers in this endeavour because as Reynolds (1992) puts it, what the teachers deem important to effective teaching and what researchers have researched and deem important often differ. This may not be too surprising considering the usually short periods of contact between the researchers and the respondents in most of the educational research. The brief contact between the researcher and the participants only serves to increase the chances of the researcher "going naive". Adopting the interpretive approach, the study was guided by the qualitative-phenomenological hypothesis, namely, which states that human behaviour can only be comprehended when the framework which individuals use to interpret their thoughts, feelings, ideas, actions and interactions is understood (Marjoribanks, 1991). In other words, it is necessary to understand the dominant culture of the school before suggesting any particular curriculum innovation. Curriculum innovations that do not appeal to the expectations of the participants in terms of what they consider to be good teaching, acceptable content to be learned and good learning practices are likely not to be successfully implemented.

It is from this theoretical stance that a three-point Likert type teacher questionnaire was developed. The 40 items in the questionnaire were concerned with the teachers' ideas about teaching strategies, class control and management, discipline, schemes of work, lesson planning, presentation and evaluation of the lesson content.

3.3.4.3 The Student Participation Inventory (SPI).

The Student participation inventory was intended to access the level of participation in biology lessons as perceived by the students themselves. Participation in this sense is seen to encompass more than hands on experiences. It involves any activity that creates an environment that encourages students to construct their knowledge. Viewed from this theoretical perspective, classroom discourse becomes an integral part of participation in biology lessons because it is through talk that students can make sense of their investigations. What students say, how they say it and the environment accorded them to say it, are as important aspects of participation as are the hands on activities during the lesson.

A fifty-item questionnaire on a five point Likert scale was used to collect data on students' perceptions of their participation in Biology lessons. It sought to establish the interactional patterns at the beginning of the lessons, during whole class discussions, in small group work, during demonstrations, in small group practical work, and at the end of the lesson. The students had to circle the answer that best represents their ideas amongst options, viz: always, frequently, sometimes, rarely and never.

3.3.4.4 The Students' Classroom Environment Inventory (PCEI).

The objectivist nature of teaching in science lessons often leaves the affective domain of classroom learning inadequately addressed. Though the psychological environment deals more with the less tangible aspects of learning and indeed teaching, it influences what students as a social group can learn (Walberg, 1991). In an attempt to access the social environment of the students, questionnaires are often used. In this regard, students rate how they perceive the psychological environment of their classroom. It seems apposite to use the perceptions of the students as part of the barometer for gauging classroom social environment because the students constitute a significant component of that environment.

The classroom environment measures serve at least two important functions. First, they attempt to capture the context for the teaching - learning process and second, they serve as a useful indicator for determining student level of participation and achievement. From this background, Walberg (1991:261) argues that:

> Climate measures are practical, inexpensive, and valid, and they predict learning gains more accurately than the so called objective variables such as students' social class, teacher behaviours and other characteristics, school and class sizes, and educational expenditures.

Two versions of the classroom environment inventory used in the study were: the *actual* classroom environment and the *preferred* adapted from Fraser and Fisher (1983,1986) and Fraser (1989). The *actual* was concerned with the classroom environment as the students experienced it, while the *preferred* dealt with the classroom environment as the students would like to have it in their classrooms. The process of adaptation had to be sensitive to the language of the learner and the typical perception of a classroom environment in the context of a developing nation like Botswana. English is a second (or in some cases third) language to the students. There was a need therefore, to scale down the level of language to that which the students responding to the questionnaire would easily comprehend. I leaned heavily on my experience as a science teacher at the secondary school level and as a teacher trainer to select the five P.C.E.I scales and to develop the appropriate indicator items for the scales. A total of thirty-five items were included. The items were representative of five scales of the instrument, namely, friction, satisfaction, difficulty, cohesiveness and competitiveness.

Friction results when there are disagreements, tension and opposition in the class. It is assumed that such an atmosphere could have an effect on the smooth flow of activities in the class and may even affect the realisation of learning goals. Satisfaction is concerned with the extent to which students like their subject, teacher and classmates. Difficulty explores the extent to which students consider the subject difficult. Students' perceptions about the difficulty of the subject have a bearing in the future study and inevitably career prospects of the students. It is generally observed that students opted out of the science subjects at their earliest convenience because such subjects were perceived as difficult. This resulted in the perception that science is for boys thus depriving over 50% of the school population of having any tangible experience in science. Cohesiveness refers to the intimacy and interdependence amongst classmates.

Co-operative learning strategies become more meaningful when the students are prepared to freely share their ideas with others and work with others to achieve a common goal. This is only possible if the students consider themselves necessary components of the group system. Cohesiveness in this regard becomes an important aspect of classroom environment. Competitiveness is about the extent to which the classmates compete with each other in the class to achieve certain goals. It involves competing for good results, to finish first or to find information. It becomes an important aspect of classroom environment because for one to succeed the other must fail. In real terms, it is characteristic of the examination system to act as a sifting mechanism that determines who would enter into higher education, training and employment opportunities.

3.3.4.5 The Teacher Questionnaire (TQ).

To explore the nature of practical work in biology, the constraints facing biology teachers and the objectives that are achieved amidst these constraints, an adapted version of the teacher questionnaire developed by Ogunniyi (1977) was used. It consisted of three sections. The first section dealt with the nature of practical work. A total of ten questions were asked to explore the nature of practical work in biology lessons. Teachers responded by circling the appropriate frequency of occurrence of such an event along a five point Likert scale, where 5 meant "frequently used", 4 meant "used", 3 meant "occasionally used", 2 meant "rarely used" and 1 meant "never used". The second section was concerned with the factors affecting practical work in biology and teachers responded to twelve questions by circling the appropriate response as to whether a factor was satisfactorily handled, not satisfactorily handled or was a serious impediment. And the last section explored the efforts teachers made to encourage the development of process skills in biology.

3.3.4.6 The Student Questionnaire (SQ).

A lot of literature on exemplary practice tends to emphasise the perspectives of the researchers and teachers rather than those of the students. This study recognises the central part played by the students in defining the complexion of any lesson. A hermeneutic perspective of teaching and learning should take into account the perspectives of the learners about teaching and learning. The student questionnaire was developed by the researcher to capture the students' perceptions of an exemplary teacher. The instrument underwent the process of validation with other instruments as described under 'Validity and reliability' in this chapter. This instrument contained thirty-two items for students to respond to in an attempt to describe an exemplary teacher. The themes across the instrument ranged from lesson preparation, class management and control, classroom environment, student-teacher characteristics, to scheme of work and planning. To respond to this instrument, the students had to circle the appropriate letter depending on whether they agreed, disagreed or were undecided.

3.3.4.7 The student interview schedule (SIS).

To further probe the students' perceptions and ideas about exemplary teaching and learning, a semi-structured interview schedule was produced and administered to the students when they finished using the exemplary package. The questions required information regarding the achievement test the students wrote, the practical work they did using the exemplary package, what they considered to be their levels of participation and how the package could have enhanced the learning outcomes.

Group interviews were used instead of individual interviews. This was necessary because of not only the obvious cost in terms of time and materials spent interviewing individuals, but also because interviewing students in a group helps recreate the ideas about classroom experiences much better than when individuals are interviewed. According to Burns (1989:47) "...most researchers cost individual interviews at the opportunity cost of not conducting a group discussion, which makes them luxury goods indeed!".

It is also in the group interview that students can clarify their interpretations and meanings they attach to phenomena in a less threatening environment. The group also reduces the interview stress on the participant.

3.3.4.8 The Teacher Interview Schedule (TIS).

A semi-structured teacher interview schedule was developed to explore the teachers' beliefs, metaphors, ideas and perceptions about the exemplary teaching package. It also explored the views of the teachers about the achievement test that the students wrote as well as the constraints they experienced working with the exemplary materials.

3.3.4.9 The Biology Achievement Test (BAT).

A 26-item achievement test was developed to measure cognitive achievement of the students in the treatment and control groups. The exemplary learning materials were designed such that students negotiated meanings and constructed their own knowledge as they interacted with the learning materials. It was a conscious effort to avoid a situation where the learning activities would encourage students to memorise things. In the same spirit, the achievement test was set in such a way that it was thought provoking.

After going through a rigorous validation process and pilot testing, the original instrument, which consisted of 60 multiple choice questions, was reduced to 26 questions. The items consisted of a mixture of multiple choice and true of false questions, which allowed the students to explain their responses. In this regard, Ahmann's (1968) suggestion that the difficulty level of suitable test items be around 50% was put into consideration. Reliability coefficients of 0.73 and 0.77 respectively were obtained using the split-half and the Spearman-Brown formula. According to

Cohen and Manion (1989:168), correlation within this range 'make possible group predictions that are accurate enough for most purposes'.

3.3.5 Corroboration framework.

Once the nature of data to be collected was established, the next issue was to determine the appropriate methods to collect such data. The use of multiple research methods is characteristic of good research practice. When several research methods are used to explore a phenomenon, this is often referred to as *triangulation.* According to Denzin (1978:308), triangulation "can take many forms, but its basic feature will be the combination of two or more different research strategies in the study of the same empirical units".

Research methods are theory-laden tools, as such, they impose certain theoretical perspectives on reality. When different methods are employed to study some aspects of human behaviour, each of them reveals a slightly different facet of the same social and symbolic reality (Berg, 1989; Cohen and Manion, 1989). Looking at the phenomena from these different vantage points, provides researchers a better chance of explaining the richness of the complex human behaviour in more detail (Cohen and Manion, 1989). According to Berg (1989:4), combining several research methods helps researchers to "...obtain a better, more substantive picture of reality, a richer, more complete array of symbols and theoretical concepts; and a means of verifying these elements".

In the process of triangulation, researchers may use either normative or interpretive approaches or even use a combination of these (Cohen and Manion, 1989). This deals with the problem of methodological parochialism that methodologist often push for either because of their familiarity with the methods or because they think are superior to others (Cohen and Manion, 1989).

Primarily, triangulation is seen as a strategy intended to improve the validity of the research findings. This is particularly important in qualitative studies whose main criticism over the years has been lack of stringent research approach and subjectivity of the findings. Triangulation has emerged as a viable technique to reduce bias and hence increase the credibility of research findings in naturalistic and qualitative inquiries. This method seems particularly appealing to qualitative researchers because the traditional scientific techniques of validation can not be meaningfully applied when these alternative epistemologies are used in a research study (Wiersma, 1986; Mathison, 1988). Information from different sources is compared to find out if there is corroboration or not. Hence, triangulation is concerned with establishing whether or not there is convergence in the data collected. It purports to establish whether or not the data collected are sufficient. Data that are inconsistent and non-convergent are regarded as insufficient (Wiersma, 1986; Mathison, 1988; Berg, 1989).

Mathison (1988) argues that while triangulation provides a rich and complex account of the phenomena being studied, it does not always lead to convergence. It often leads to inconsistency and contradiction. He argues that the value of triangulation is not that of validation, but that it provides a forum for researchers to account for the same phenomena in a multiplicity of ways, that is, constructing possible and plausible explanations of the data and about the data. According to Mathison (1988:15):

> The value of triangulation is not as a technological solution to a data collection and analysis problem, it is as a technique which provides more and better evidence from which researchers can *construct meaningful propositions* about the social world. The value of triangulation lies in providing evidence such that the researcher can construct explanations of the social phenomena from which they arise.

In this study, the value of triangulation was seen to go beyond corroboration, but to encompass the hermeneutic and phenomenological perspectives as well. In other words, it is a method that seeks both corroboration and the clarification of meanings of data. According to Mathison (1988:17), this is a more realistic stance because even

> Practising researchers and evaluators know that the image of data converging upon a single proposition about a social phenomenon is a phantom image. More realistically, we end up with data that occasionally converge, but frequently are inconsistent and even contradictory.

It is apposite therefore, to see triangulation not only as a technique that seeks to establish convergence, but also as an approach that enables the researcher to have a holistic image of the social phenomenon.

Since part of what triangulation purports to achieve is to enhance the validity of the data, it can as a result be applied at different stages of the research project. For this reason, different types of triangulation have been identified. Denzin (1978:294-307), identifies these as data, investigator, theory and methodological triangulations. The three types of triangulation that relates to this research work are the data, investigator and methodological triangulations.

Data triangulation involves the use of a variety of several sources of data. It includes both the time and space triangulation since to understand a social phenomenon, one must understand it under varied conditions. These could include collecting data at different times to include the effects of social change and process (time or space), or collecting data across cultures (Denzin, 1978; Mathison, 1988; Cohen and Manion, 1989).

Investigator triangulation involves the use of more than one investigator to explore the phenomena being studied. In this particular case, it takes more personnel to accomplish the process of data collection. Each investigator has a different feel for the data to be collected and collects what he/she perceives as meaningful and appropriate data and this eliminates the problem of investigator bias (Denzin, 1978; Mathison, 1988; Cohen and Manion, 1989).

Methodological triangulation results when a variety of methods are used to investigate a social phenomenon. A distinction is made by Denzin (1978) and others between *within methods* and *between methods* triangulation. In the former, the main thrust of triangulation is replication of the study. This goes a long way to establish the reliability in the data collected (Cohen and Manion, 1988). Within methods triangulation essentially involves one method of data collection. For this reason, its utility to corroborate data is limited. The latter triangulation carries with it the notion of multiple method approach in which it is assumed that the weaknesses of one method are the strengths of the other (Mathison, 1988). This suggests that the bias inherent in one research method, source of data or investigator is masked by the strengths of the appropriate data sources, investigators or methods used in conjunction with it.

3.4.0 Validity and Reliability.

To ensure that this study and the instruments used measure what the study purports to measure, and that the study and the instruments used will give comparable results when used again to collect the same kind of data, several corroboration techniques were used. As stated earlier, triangulation was used partly as a corroboration framework. This involved the use of multiple methods such as participant observation, survey questionnaires, and formal and informal interviews. Also, data triangulation with more than one source of information was used.

The sources of information included: (i) students who were interviewed, responded to classroom environment inventories and student questionnaires; (ii) teachers who were involved in formal and informal interviews and responded to the survey questionnaires; (iii) classroom observations involving the students and teachers in the natural classroom setting and (iv) the Biology Achievement Test. Researcher triangulation constituted the third level of triangulation used in the study. Here, two research assistants were trained to use BLIOS to code the lesson interactions. The assistants were trained to achieve 95% agreement. The researcher bore in mind Wragg's (1994) suggestion that if the inter- or intra-coder agreement is less than about 70% then the results should be interpreted with caution. The use of multiple coders ensured that experimenter bias was kept to the minimum.

All the instruments used in this study underwent the due process of validation. The steps taken in the process included a thorough scrutiny of the instruments by a panel of ten experienced teachers who gave their comments about their suitability for gathering the required data. They were specifically required to: (i) assess whether or not, the level of the language used is appropriate for the target students, (ii) whether or not, the concepts were presented in such a way that they were easily comprehensible to the students and whether the questions asked in the Biology

Achievement Test were asked at the appropriate level and measured what was taught to the students. After several revisions, the instruments were passed on to a panel of six professionals with a strong research background in Science education at the University of Botswana. They were asked to: (i) assess the level of the language used, (ii) assess whether or not the questions were presented in a logical manner, (iii) assess the clarity of questions and identify overlapping and poorly structured questions. Their comments were used to refine the final versions of the instruments. All the instruments were trial tested in a class comparable to those involved in the actual study. Particular attention was paid to the level of the English language used in the instruments, the interpretations pupils made of the different items, the instructions and the objectives of the instruments.

A pilot study was conducted in three senior secondary schools in which the curriculum package, and all the related instruments were administered. During the pilot study, the exemplary teachers used the exemplary teaching protocols in their lessons for a period of six weeks. They administered the questionnaires to the students. Throughout the six weeks, the teachers kept journals of their classroom experiences. This provided an insight into some of the shortcomings of the research procedures. For instance, the pupil's questionnaires and the inventories were found to be too many. To resolve this, the instruments were divided amongst the classes, such that each class responded to half the number of the instruments. In this way, each class had to respond to two instruments. The teachers also complained about the enormity of their tasks, viz: preparing for the lessons, teaching in the suggested way and then sitting to write the journals. To strike a compromise, some of the key things they could use as their baseline data without necessarily restricting their ingenuity were outlined for them. Some parts of the instructions in the pupils' workbook were taken for granted, and it was realised that some students would not proceed well without such instructions. Some experiments were taking longer than was budgeted for and as such some adjustments had to be made while some were both teacher and student proof in that they did not allow for any sort of creativity and ingenuity from the students and teachers. Ways of allowing for more flexibility and input from the teachers and their students were sought. For instance, when doing food tests, some teachers felt there are certain food samples that worked a lot better than those suggested in the lessons. In such cases, the researcher tested the food samples and those, which were found suitable, were incorporated in the workbook.

3.5.0 Cases Studies

3.5.1 Participant Observation.

Understanding the participants' perspectives was central in this study. For this reason, participant observation as opposed to non-participant observation or non-obtrusive methods of observation was chosen. Participant observation offered the opportunity to experience phenomena and try to understand it from the point of view of the participants. From this vantagepoint, the interpretations of phenomena took cognisance of the views of the participants.

A review of the literature on the classroom dynamics in science in Botswana as mentioned earlier, reveals a generic dearth of ethnographic studies by people who are familiar with the culture and belief systems of the participants. Most of this research has been done by western researchers who are alien to the cultures concerned (e.g. Fuller and Snyder, 1991; Prophet, 1990; Prophet and Rowell, 1990). This is particularly important because during science lessons, students tend to use their vernacular languages despite the official requirement for them to use the English language. Perhaps this is the reason why none of such researchers (in so far as this investigator is aware) has accounted for the processes of negotiation of meanings in small groups in science lessons in general and biology lessons in particular. This makes this study an important one in that it is probably the first of its kind to explore these processes in small group work in biology lessons in Botswana.

3.5.2 Classroom Observation.

As stated earlier, holistic images of classroom life cannot adequately be attained through the use of positivist approaches alone because they tend to reduce data to what is codeable. Such approaches tend to fragment data into pre-specified categories that do not allow the researcher to add on new categories when behaviours which may not be fitting into the coding system are encountered (Delamont and Hamilton, 1984,1993). Hence, data that cannot be captured by the coding system are, therefore, not accounted for as part of the classroom ecology. Systematic coding systems also tend to ignore the context under which the overt behaviours reported actually happened. As a result, the interpretations and meanings underlying such behaviours are irretrievably lost. Data collected this way tend to be devoid of the meanings and interpretations intended by the observed.

The researcher spent over eighty hours observing lessons in six senior secondary schools in Botswana between May and October 1996. During the period, a variety of observation techniques were used to collect relevant data on life in biology lessons. The BLIOS was used to collect data on the nature of teacher-student interactions. This included the verbal and non-verbal interactions of the teachers and students. To compensate for the limitations of the coding schemes as indicated earlier, other data collection instruments including video and audio recordings of classroom interactions and a number of participant observation techniques were used. The video recorder was used to record interactions in small groups. This was considered to be a valuable source of information on students' participation during group work and group discussions. It was thought that an analysis of these procedures (including the record of classroom talk) would shed some light on the power struggle across and within gender lines and/or across pupils of different academic abilities as well as reveal the process in the negotiation of meanings and roles in the biology lessons. Whenever the tape or video recorder was used, the researcher had the opportunity to make copious field notes. A summary of the main trends in the field notes and the tape transcripts was done shortly after the lessons. Informal discussions were also carried out whenever there was need and when things were still fresh in the minds of the teachers and the students.

During classroom observations the interactions between students, the students and the teacher, male and female students, and students and materials were observed. Also, recorded were the way teachers treated responses from the male and female students, how the male and female students attracted the teacher's attention and how the male and female students reacted to utterances made by others during group work and group discussions. Lastly, the way all the stakeholders in the class played different roles and negotiated meanings and reached consensus were documented.

3.6.0 Research design

The form three (grade 10) students in Botswana senior secondary schools are not streamed. So each class was assumed to represent a fairly heterogeneous sample of students. The quasi-experimental research design used in this study was modified from Solomon Three Control-Group Design.

Table 1: A research design used to structure a study on exemplary practice.

Pre-test	Treatment	Post-test	
O_{cp1}	x	O_{cp2}	(E_1)
	x	O_{cp3}	(C_1)
O_{cmp1}	x	O_{cmp2}	(E_2)
	x	O_{cmp3}	(C_2)
O_{ind1}	x	O_{ind2}	(E_3)
	x	O_{ind3}	(C_3)
O_{cnt1}		O_{cnt2}	(C_0)

Where:

E_1 is the co-operative treatment group which received both the pre- and post-test.

C_1 is the co-operative treatment group that received the post-test only.

E_2 is the competitive treatment group which received both the pre- and post-test.

C_2 is the competitive treatment group that received the post-test only.

E_3 is the individualistic treatment group which received both the pre- and post-test.

C_3 is the individualistic treatment group that received the post-test only.

C_0 is the true control group.

The design controls for the effect of the pre-test. However, since intact classes were used, it was necessary to ascertain the comparability of the groups. An analysis of the F-value indicated that the groups were quite comparable (Table 2).

Table 2: Analysis of variance of all the pre-test scores.

Var.	Source	D.F.	SS	MS	F Ratio	F Prob.
Groups	Between groups	3	427.2609	142.4203	1.8198	.1440
	Within groups	252	19722.177	78.2626		

To minimise the effects of the teacher, the experimental group and the control group were taught by the same teacher. In most cases the lessons were taught the same day. This reduced the stress of preparing the same materials all over again on a different day for the other class. As much as possible the questionnaires, tests and classroom environment inventories were administered the same day.

3.7.0 Analysis of data.

The eclectic approach adopted in this study inevitably warranted the use of compatible data analysis. Data resulting from this study were both quantitative and qualitative and as such both descriptive and inferential statistics were used to analyse the findings.

A review of studies done by Bryman and Burgess (1994) reveals various ways in which qualitative data may be analysed. Amongst these, they site the work of Tesch (1991) who distinguished between two approaches to qualitative data analysis. According to Tesch, certain analyses concentrate on language, e.g. discourse analysis, symbolic interactionism and ethnomethodology. In such analytic approaches, the focus is language as a mode of interaction and how it is used in this interactive process. There is also the 'descriptive or interpretive approach' that is concerned with establishing a 'coherent and inclusive' perspective of the cultural ecology of a social setting from the point of view of the participants.

While this study was more inclined to the interpretive approach, aspects of discourse analysis were not altogether neglected. Of particular interest in the discourse analysis was the rhetorical or argumentative organisation of utterances in classrooms (Potter and Wetherell, 1994; Miles and Huberman, 1994). This is particularly important in this study because student participation in biology classrooms is seen to mean more than hands-on activities but also *minds-on.* Clearly, this entails an inter- and intra-gender power struggle in that 'it takes the focus of analysts away from the questions of how a version relates to some putative reality and asks instead how this version is designed successfully to compete with an alternative' (Potter and Wetherell, 1994). A concern for rhetoric in this sense is primarily a concern about how students structure and use language such that they succeed in putting forward their ideas in such a way that they out compete alternative ideas from the group. As such, the way the students and teacher alike, choose their words, emphasis and diction, stems from a purpose; these 'are potentially part of the performance of some act or are consequential in some way for the outcome of the interaction' (Wooffit, 1990; Potter and Wetherell, 1994). A concern for rhetoric is to a large extent a concern for accountability. In an attempt to make one's ideas accountable, one is restructuring such ideas in such a way as to make them difficult to rebut. As such, accountability should be seen to be transcending any stretch of discourse (Potter and Wetherell, 1994).

3.8.0 Limitations of the study.

This study was limited to schools along the railway line, which could be reached easily on a normal two-wheel drive vehicle. The study was therefore, limited to schools around Gaborone (the capital city of Botswana), Lobatse and Francistown. The distances between these places were enough not to allow for contamination of one treatment group from the other. For instance, the co-operative treatment schools in Francistown were over four hundred kilometres from the individualistic treatment schools in Gaborone and Ramotswa. These too were over thirty kilometres from the competitive treatment schools in Otse and Lobatse. The control group school was sixty kilometres east of Gaborone and far detached from any of the treatment schools.

Due to the very high cost of producing students' workbooks, only four hundred and forty-six students were involved in this study. Workbooks also proved to be a problem as other students in higher forms and those in form three but were not in the study tended to do the best they could to acquire these regardless of what that entailed. So the rate at which they got lost or the cost of replacement became a source of concern.

CHAPTER FOUR.

4.0.0 Results and Discussion.

4.1.0 Introduction.

The study attempted to: (i) explore biology teaching in Botswana and (ii) determine the relative effects of exemplary practice on the students' participation and achievement in biology. The data obtained from the study are analysed both quantitatively and qualitatively. This is to capture the holistic picture of classroom interactions and the processes of knowledge construction which serve as the focus of the study.

4.1.1 The interaction behaviours of biology teachers and students in exemplary and conventional teaching-learning models.

Classroom life is largely characterised by talking. It is through talking that teachers transmit knowledge, direct and exert authority, encourage pupils to display desired behaviours germane to a conducive classroom environment. Students through talk, request for help, seek for clarification and information or demonstrate their understanding. Undoubtedly, classroom talk is an important component of teaching and learning. A review of the literature suggests that classroom discourse is often teacher dominated - a phenomenon that could be counter-productive when construction of knowledge by students is the desired goal. Table 3 indicates the percentage of verbal and non-verbal interactions in the exemplary and normal biology lessons in Botswana using the Biology Laboratory Interactions Observation Schedule (BLIOS).

Table 3*: *Percentage verbal and non-verbal interactions in a sample of fifty-six conventional and exemplary biology lessons.

Categories	Conventional biology lessons (%)	Exemplary biology lessons (%)
Teacher		
1. Empathises	0.3	0.2
2. Gives verbal reward	1.4	0.4
3. Accepts and reinforces response	2.1	1.0
4. Ignores student's response	0.1	0.1
5. Challenges student's response	2.4	0.7
6. Lectures	24.5	6.0
7. Questions	12.0	5.8
8. Responds to question	0.6	0.3
9. Directs	1.6	2.0
10. Supervises/Individual attention	4.5	22.4
11. Manipulates apparatus	2.9	3.4
12. Rebukes, criticises, exerts, authority	1.3	0.1
Student.		
13. Responds to question	11.6	5.7
14. Questions	1.4	0.8
15. Initiates talk	1.7	1.6
16. Experiments	19.0	46.6
17. Reads, writes and or draws	8.6	2.3
18. Non-productive activities	4.0	0.6

The frequency of occurrence of interactions (based on 10-second intervals) was converted to percentages. Descriptive rather than inferential statistics was used in the analysis of the data due to the complex nature of classroom dynamics. Also, the latter does not seem to provide a distinct advantage over the former when the phenomenon studied is as holistic and fluid as classroom interactions (Dunkin and Biddle, 1974; Ogunniyi, 1992; Ogunniyi and Ramorogo, 1994).

The results of this study suggest that the interaction patterns in the so-called exemplary classrooms were different (though not in all cases) from the conventional classrooms observed in the study. For instance, no distinct differences were observed with respect to categories viz: empathy, ignoring student's responses, responding to students' questions, directing and manipulating apparatus. However, there seems to be observable differences in other aspects of classroom interactions. The non-exemplary teachers tend to:

i) give more verbal rewards than exemplary teachers (1.4% compared to 0.4%)

ii) accept and reinforce students' responses more than exemplary teachers (2.1% compared to 1.0%).

iii) challenge students' responses more than exemplary teachers (2.4% compared to 0.7%).

iv) lecture more than their exemplary counterparts (24.5 % compared to 6.0%)

v) ask more questions than their exemplary counterparts (12% compared to 5.8%)

vi) rebuke, criticise and exert authority more than exemplary teachers (1.3% compared to 0.1%)

On the other hand exemplary teachers, tend to supervise and give individual attention more than non-exemplary counterparts (22.4% compared to 4.5%).

Students in non-exemplary lessons appear to:

i) respond to more questions from the teacher than those in the exemplary lessons (11.6% compared to 5.7%).

ii) ask their teachers more questions than their counterparts in the exemplary lessons (1.4% compared to 0.8%).

iii) read, write and or draw more than their counterparts in the exemplary lessons (8.6 compared to 2.3) and

iv) be involved more with non-productive activities than those in the exemplary lessons (4.0% compared to 0.6%).

Students in exemplary lessons however, tend to do more experiments than their non-exemplary counterparts (46.6% compared to 19.0%).

Viewed in isolation, these findings seem to suggest that non-exemplary teachers are more indirect than exemplary ones. The issue here is not whether teachers should be direct or indirect but rather whether the interaction patterns they portray are conducive to construction of knowledge by students. This judgement would best be suspended till more information about verbal and non-verbal interactions in biology lessons is provided.

4.1.2 Patterns of verbal and non-verbal interactions in biology lessons.

A learning environment that espouses construction of knowledge by students should provide students with ample opportunities to experience phenomena as well as engender negotiation of meanings by the students. In other words, students should be actively involved in experiments, demonstrations and discussions both in small groups and in whole class activities in order for them to make sense of their ideas and experiences. Table 4 shows the overall verbal and non-verbal interactions in a sample of conventional and exemplary classes.

The overall teacher verbal interactions in a sample of conventional biology lessons are 50% against 39% for exemplary teachers. The student verbal interactions in the conventional biology lessons are 33.7% against 54.7% in exemplary biology lessons. In other words, non-exemplary teachers seem to out-talk their students. This finding corroborates earlier studies in Botswana (Rammiki. 1991; Fuller and Snyder, 1991; Ogunniyi and Ramorogo, 1994) which suggest that teachers out-talk their students in science lessons. Students in exemplary lessons however, seem to talk more than their teachers. This pattern of classroom interactions in a supposedly traditional society is worthy of notice.

Table 4: Overall verbal and non-verbal interactions in a sample of conventional and exemplary biology lessons.

Categories	**Conventional biology lessons (%)**	**Exemplary biology lessons (%)**
Teacher verbal interactions	50.7	39
Teacher non-verbal interactions	3.0	3.5
Student verbal interactions	33.7	54.7
Student non-verbal interactions	8.6	2.3
Non-productive activities	4.0	0.6
Teacher verbal and non-verbal interactions	53.7	42.5
Student verbal and non-verbal interactions	42.3	57.0
Non-productive activities	4.0	0.6

Teacher verbal and non-verbal interactions constitute 53.7% in the conventional biology classes against 42.5% in the exemplary classes. Student verbal and non-verbal interactions are 42.3% in the conventional classes and 57.0% in the exemplary classes. This suggests a fundamental difference in the two classroom environments. The teachers in the conventional classes tend to dominate the verbal interactions while the students in the exemplary classes seem to exhibit greater verbal interactions. The latter is not unrelated to freer student-student interactions allowed by the exemplary teachers for the purpose of knowledge construction among students.

Table 5: Percentage of types of questions asked by teachers during a sample of conventional and exemplary biology lessons.

Type of question	Conventional biology lessons (%)	Exemplary biology lessons (%)
Factual/information	50.30	52.10
Rhetorical	20.80	12.61
Leading	5.80	7.14
Probing	23.10	28.15

Table 5 shows proportions of four types of questions teachers ask in the conventional and exemplary lessons. While there appears not to be much difference between the factual questions used in the conventional and exemplary teachers ask, there seem to be marked differences in other forms of questions asked. The teachers' questions in both cases are predominantly factual, i.e. 50.30 and 52.10% for the former and the latter respectively. In other words, about half the questions asked during the biology lessons were in fact, factual. The tendency for teachers to ask predominantly factual questions has been frequently encountered in earlier studies (Ogunniyi, 1983; Rammiki, 1992; Ngueja, 1992; Fuller and Snyder, 1991 and Ogunniyi and Ramorogo, 1994). This pattern of interactions may not be unrelated to the fact-oriented Cambridge Ordinary Level Certificate (COSC) examination questions. While the efficacy of using more higher order questions over factual questions to enhance learning awaits further corroboration, factual questions tend to be associated with methods of instruction that encourage rote learning (Gall, 1970; Ogunniyi, 1981;1983; Ogunniyi and Ramorogo, 1994). As regards other types of questions, teachers in the conventional biology lessons seem to ask far more rhetorical questions (20.80%) than their counterparts (12.61%) in the exemplary lessons. They however, ask fewer leading and probing questions than exemplary teachers (i.e. 5.8% compared to 7.14% and 23.10% compared to 28.15% respectively). If learning is perceived to involve construction of knowledge by the learner, it would seem appropriate that teachers should involve the learners in a process of negotiating meanings. This goes beyond reception of teacher transmitted knowledge to a conscious reflection on one's own experiences, ideas, belief systems and the sense one makes of these. A situation where teachers ask more rhetorical questions and fewer leading and probing questions might encourage less of sense making from their experiences than otherwise is the case. It probably reflects a scenario where teachers perceive learning as mere transmission of knowledge.

While the exemplary teachers ask generally fewer questions in their lessons, the quality of their questions in terms of leading and probing questions is higher than that of the conventional teachers. If learning is considered to involve a move from viewing the learner as a passive recipient of information to the one that engenders the negotiation of meaning and knowledge construction, then it seems reasonable to expose the learners to questions that would challenge them to organise their thoughts in such a way that would result in meaningful learning. A preponderance of rhetorical and factual questions does not seem to be conducive to the development of the kind of critical thinking necessary for such a construction of knowledge or negotiation of meanings.

4.2.0 Relative effects of co-operative, competitive and individualistic laboratory interaction models on students' participation and achievement.

The issue of competition, co-operation and individualism are probably recognisable in every society, no less the one where students involved in this study come from. The phenomenon forms an important part of the socialisation process that students bring into the learning situation. The tables in the following sections provide a quantitative analysis of the data obtained from the three groups of subjects using the competitive, co-operative and individualistic learning approaches in the study of biology.

Due to the plethora of codes used in the study, it is apposite to re-present terms used for the various groups for ease of reference:

E_1 is the co-operative treatment group which received both the pre- and post-test.

C_1 is the co-operative treatment group which did not receive a pre-test.

E_2 is the competitive treatment group which received both the pre- and post-test.

C_2 is the competitive treatment group that did not receive a pre-test.

E_3 is the individualistic treatment group which received both the pre- and post-test.

C_3 is the individualistic treatment group that did not receive a pre-test.

C_0 is the true control group.

Table 6: Analysis of Variance of pre-test and post-test scores of the BAT according to groups and sex.

Variable	Test	Source	D.F.	SS	MS	F Ratio	F Prob.
Groups	Pre	Between groups Within groups	3 252	427.2609 19722.1766	142.4203 78.2626	1.8198	.144
	Post	Between groups Within groups	6 439	112456.221 46196.1136	18742.704 105.2303	178.11	.000
Sex	Pre	Between groups Within groups	1 254	2072.7182 18076.7193	2072.7182 71.1682	29.124	.000
	Post	Between groups Within groups	1 444	37.7702 158614.56	37.7702 357.2400	.1057	.745

Significant at $p< 0.05$

The F ratio for the pre-test scores in the co-operative, competitive, individualistic and true control groups is 1.82. This value is less than the critical F ratio at $F_{(3,252)}$ needed to suggest significant differences among the four groups. In other words, the groups of subjects were quite comparable even before they were exposed to exemplary teaching and learning strategies. When the pre-test scores were analysed according to sex, a significant difference between the performance of boys and girls was observed. An observed F ratio of 29.12 is greater than the critical ratio of $F_{(1,254)} = 2.65$ at $p<.05$ needed to indicate a significant difference between the two sexes. In other words, despite the overall homogeneity of the groups, the boys and girls in this study did not seem to be at the same level of performance. While it would have been desirable to regress this situation, it was left unabated because among other things, this study explores the effects of sex and academic ability on the participation and achievement of students. As such this disparity on the performance of boys and girls in the pre-tests, though not planned, is an important starting point in exploring the effects of exemplary practice on students of different academic abilities.

The F-ratio for the post-test scores in all the groups is 178.11. This F ratio is far greater than the critical value for $F_{(6,439)}$ needed to falsify the null hypotheses. This suggests a significant difference between the post-test scores of the groups involved in the study. When the post-test scores are analysed by sex however, an insignificant F ratio of 0.1057 is obtained, suggesting that the post-test scores for the boys and girls in the different groups in the study have become relatively homogeneous. A comparison of the pre-test and post-test scores by sex for the treatment group (C_0) reflects that a significant difference in the performance of boys and girls both at the pre-test and post-test stages. The F-value obtained for the pre-test was 4.38 while that for the post-test was 4.01. This seems to suggest that the traditional teaching strategies did not effectively create the necessary learning environment required to reduce the critical gap in the achievement of boys and girls in conventional classes. To explore the differences and similarities in the performance of students in the different groups and sexes, a comparison of means was performed and the Scheffe test of significance was used to determine the strength and direction of the relationships. Table 7 shows a comparison of means of the pre-test and post-test scores of the Biology Achievement Test according to the groups and sex of the subjects.

Table 7: ANOVA of the pre-test and post-test BAT scores according to groups and sex of the subjects.

Variabl e	Variable label	Pre-test		Post-test	
		Mean	SD	Mean	SD
Group	E_1	21.6667	8.9809	63.4848***	8.2224
	C_1			60.6094***	10.7003
	E_2	20.0952	10.4999	65.1111***	8.4569
	C_2			62.8571***	9.5290
	E_3	23.4194	7.5478	32.8710	11.7661
	C_3			30.5714	10.3202
	C_0	23.0154	8.0710	29.7538	12.1681
Sex	Male	24.7407	7.7978	49.1154	18.1503
	Female	19.0413	9.0962	49.6981	19.6964

* Significant at $p < 0.05$

The pre-test means for groups E_1, E_2, E_3, and C_0 are not significantly different from each other. The pre-test means by sex of the students, however, suggests that boys out-performed the girls. The tendency for boys to perform better than girls in science has a long and disturbing history. Administering a pre-test to groups E_1, E_2, E_3, does not seem to have given the students in these groups any leading edge above their counterparts in groups C_1, C_2, and C_3 who were not exposed to the pre-test. When post-test scores are analysed by sex, there seems to be no significant difference in the performance of boys and girls in all the groups in the study. That is, the initial difference in the performance of the two sexes seems to have disappeared. As such, the pre-test and the sex of the students do not seem to explain the cognitive gains of the students.

There seems to be no significant difference in the performance of students in the groups E_3 and C_3 compared to those in the C_0 group. This lack of significant cognitive gains in individualistic interaction models of instruction over the traditional ones has been encountered before (Ogunniyi and Okebukola, 1984). There are however, significant differences in the performance of students in the co-operative (E_1, C_1) and competitive (E_2, C_2) groups compared to the control group (C_0) respectively. However, unlike Okebukola (1985) there seems to be no significant differences in the cognitive gains of students in the co-operative and competitive experimental groups. Sherman (1989) also reported a similar finding that neither of the two interaction models seems superior to the other. While the students in the individualistic, co-operative and competitive groups all used the exemplary materials to study biology, the lack of significant cognitive gains in the individualistic group seems to suggest the importance of the social environment in the learning process. It appears that the use of exemplary materials in the individualistic environment was bereft of the sense making process that constitutes meaningful learning. Peer interaction seems to be catalytic of such a sense making process. As such higher cognitive gains seem to result when knowledge that is personally constructed is socially mediated.

4.3.0 The students' gender and academic ability and their participation and achievement in biology.

The gender of the student is an important factor in classroom interactions for several reasons. The most compelling reason is that unlike sex which simply implies that an individual is either male or female, gender refers to the manner in which males and females are socialised into socio-cultural roles (Dirasee, 1990). For this reason, the manner in which the students are socialised into their socio-cultural roles would be expected to affect the way they would interact and participate in biology lessons as well as their perceptions of their roles in the learning environment. In Table 6, an analysis of variance for scores on the Biology Achievement Test for the co-operative, competitive, individualistic and the true control group against the sex of the students shows no significant differences in the post-test scores of the students. Thus, exposing students to the exemplary teaching and learning materials seems to have regressed the achievement of the students towards the mean. In a sense, the girls have improved their performance towards the mean while the performance of the boys seems to have regressed towards the mean. The mean score for boys is 49.11 while that for girls is 49.69 suggesting that the performance of both sexes is uniform after exposure to the exemplary practice.

The influence of gender on learning can be viewed from a variety of perspectives. From a behaviourist perspective, the external stimuli applied to the student would cause him/her to behave in a certain way. That is, the student would behave the way he/she is rewarded to respond. In this sense, if a teacher and or parents reward the student to display certain feminine or masculine behaviours, he/she will learn such behaviours and display them when the appropriate stimuli are presented. This study however, does not seem to condone this view, in the sense that the boys in this perspective would be expected to have maintained their advantage and continued to out- perform the girls.

Viewed from a social contructivist perspective however, when the student is socialised into the culture of the society, he/she does not simply imbibe the cultural matter presented to him/her, but rather actively interacts with such matter making sense of it and in the course of this interaction making judgements about what constitutes his/her own reality which would in turn determine how he/she wants to behave. Hence the way the student behaves is largely a matter of his/her interpretations of the cultural cues he/she receives. Task specialisation espoused in the exemplary teaching protocols in this study, might have made it possible that students irrespective of gender should get ample opportunities to interact with the learning environment and make sense of their experiences. As a result, reducing the effects of social stereotypes that the learners may bring into the learning situation. The effects of exemplary practice on the students' performance may not only reduce the disparities between the achievement of boys and girls, but also the achievement of students of different academic abilities. Table 8 shows an ANOVA of the mean scores for groups E_1, E_2, E_3 and C_0 with respect to academic achievement of the students in their pre- and post-test. Using pre-test scores, students in these groups were divided into low, average and high ability subgroups.

Table 8*: *ANOVA of the pre-test and post-test scores of the low, average and high ability students on the Biology Achievement Test.

Group	Test	Source	D.F.	SS	MS	F Ratio	F Prob.
E_1	Pre	Between groups	2	3992.9889	1996.4944	100.650	.0000
		Within groups	63	1249.6778	19.8362		
	Post	Between groups	2	16.9889	8.4944	.1135	.8928
		Within groups	63	4713.0111	74.8097		
E_2	Pre	Between groups	2	6110.9195	3055.4597	253.037	.0000
		Within groups	60	724.5091	12.0752		
	Post	Between groups	2	111.5175	55.7587	.5300	.5914
		Within groups	60	6312.8000	105.2133		
E_3	Pre	Between groups	2	2455.4861	1227.7430	71.0436	.0000
		Within groups	59	1019.6107	17.2815		
	Post	Between groups	2	5783.5295	2891.7648	64.1060	.0000
		Within groups	59	2661.4382	45.1091		
C_0	Pre	Between groups	2	3389.0855	1694.5427	134.712	.0000
		Within groups	62	779.8992	12.5790		
	Post	Between groups	2	2085.2496	1042.6248	8.9156	.0004
		Within groups	62	7250.5042	116.9436		

Significant at $p < 0.05$

Two trends seem to emerge from Table 8. First, is a situation where the variance in the pre-test scores of the students in the sub-groups (low, average and high ability) within groups E_1 and E_2, seem to disappear in the post-test. That is, in the pre-test, the F ratios of 100.65 and 253.04 are observed for groups E_1 and E_2 respectively in relation to the performance of the students of the three academic abilities in each group. These F ratios reflect significant differences in the performance of low, average and high ability students in these groups. In the post-test however, F ratios of 0.1135 and 0.5300 are obtained for these groups. These F ratios suggest that there is no significant difference in the performance of the students of the different ability levels after they are exposed to the co-operative and competitive teaching and learning strategies. Second, is that the variance observed in the pre-test scores for the average and high ability students in these groups. In the post-test however, F ratios of 0.1135 and 0.5300 are obtained for these groups. These F ratios suggest that there is no significant difference in the performance of the students of the different ability levels after they are exposed to the co-operative and competitive teaching and learning strategies. Second, is that the variance observed in the pre-test scores for the different ability levels of the students in groups E_3 and C_0 persist in the post-test though for different reasons. A comparison of the mean scores (using ANOVA) gives an insight into the differences in the performance of the students of different academic abilities in groups E_1, E_2, E_3 and C_0.

***Table 9**: Comparison of means of the pre- and post-test scores for the low, average, and high ability students on the Biology Achievement Test.*

Group	Ability	Pre-test		Post-test	
		Mean	SD	Mean	SD
E_1	Low	10.8889	3.4281	63.7779	8.1425
	Average	23.5500*	4.7607	62.8000	8.6148
	High	36.5000**	4.8697	62.2500	9.9391
E_2	Low	11.5152	3.6753	64.6667	6.3868
	Average	23.7333*	3.1952	62.1333	14.5694
	High	35.3333**	3.2660	65.8667	12.0586
E_3	Low	12.1818	3.2808	14.7273	6.5892
	Average	23.6923*	4.8458	33.8974*	7.1664
	High	32.8333**	1.3371	46.1667**	5.0061
C_0	Low	12.7059	3.1576	20.7059	4.0584
	Average	23.8235*	4.1595	34.2353*	13.3736
	High	33.5714**	1.9499	30.7143*	9.1351

* Scheffe test with significance level .050

While in the co-operative (E_1) and competitive (E_2) groups, the low ability students seem to have made the greatest cognitive gains, this does not seem to be the case in the individualistic (E_3) and true control (C_0) groups. Individualism seems to have no particular advantage for any ability group. The Scheffe test of significance suggests that in the individualistic group (E_3), the low ability students performed least and the high ability students performed better than the other ability levels in both the pre- and post-test. Perhaps, the lack of social interaction for the students in all the ability levels deprived students the opportunities to share and evaluate their ideas in the social environment of peer interaction. In the conventional group (C_0), the average ability students seem to have benefited from the learning experiences more than the slow and the high ability students. While in the pre-test, the low achievers had performed least and the high ability students had performed better than the other two levels of ability, during the post-test, there was no significant difference between the performance of the average and the high ability students. Thus, conventional teaching strategies seem to have had insignificant cognitive impact for the slow and high ability students. It is acknowledged that these findings represent the performance of students on a small slice of knowledge. Perhaps, future studies should attempt to explore the effects of a broader spectrum of topics over a longer period of time than was available for this study.

4.4.0 Working against the grain? Teachers' and students' ideas of exemplary practice.

The notion that teaching and learning are complex, variegated and dynamic activities is unequivocal (Ramorogo, 1996; Ramorogo and Kiboss, 1997). If this is the case then, exemplary practice cannot be a context free activity. In other words, exemplary practice is embedded in a contextual matrix of belief systems of both the teachers and the students alike.

Table 10 shows a rank order of the traits of an exemplary biology teacher from the point of view of students. The students' responses were tallied up and the mean score for each statement describing an exemplary biology teacher was calculated. The student response categories 'Agree', 'Disagree' and 'Undecided' were ascribed values, '3 = agree', '2 = undecided' and '1 = disagree' respectively. Statements that the students strongly feel characterise an exemplary biology teacher have mean scores approaching three while those that are taken not to represent such a teacher have mean scores approaching one.

Table 10: Students' perceptions of an exemplary biology teacher.

Statement	Mean score	Rank order
Encourages students to participate actively during the lesson	2.97	1
Gives homework related to work done and mark it	2.97	1
Encourages memorisation for tests and examinations	2.92	3
Makes sure students are on-task and not playing during the lesson	2.87	4
Always has instructional materials ready before the lesson	2.84	5
Provides appropriate and adequate material for the lesson	2.82	6
Writes on the board clearly and regularly	2.75	7
Gives verbal rewards for correct responses	2.73	8
Encourages students to plan and carry out experiments	2.73	8
Encourages students to discuss tasks in small groups	2.70	10
Tries to understand things from the students' point of view	2.62	11
Speaks very softly so that students listen very carefully	2.55	12
Allows students to ask questions and make suggestions freely	2.54	13
Allows no one to talk during lessons unless asked by the teacher	2.49	14
Always decides the groups students should work in	2.48	15
Uses practical work to clarify and confirm theory	2.47	16
Criticises, rebukes and warns students about their behaviours	2.45	17
Teaches at a pace and manner that ensures understanding	2.45	17
Provide students with opportunities to do experiments	2.40	19
Covers the syllabus fast enough for the examinations	2.37	20
Wastes no time cleaning the board but finds a clean part and uses it	1.83	21
Is not to be too familiar with students	1.79	22
Avoids embarrassing students by directing questions to them	1.78	23
Uses slow learners to determine the pace of the lesson	1.75	24
Teaches well topics most likely to come out in the examination	1.58	25
Avoids eye contact with students during the lesson	1.57	26
Does not move around the class because it disturbs the students	1.54	27
Directs questions to students who are likely to get them right	1.52	28
Ignores incorrect responses from students	1.52	28
Relates what is taught to students daily life experiences	1.50	30
Does not display laboratory rules in the laboratory	1.29	31
Uses bright students to determine the rate at which to teach	1.27	32
Allows students to answer questions in a chorus	1.23	33
Provides no opportunities for girls and weaker students to participate	1.14	34

Clearly, discussing all the statements in the questionnaire may result in a rather murky and pedantic picture of the students' perceptions of an exemplary teacher. To avoid this, only the top ten and the bottom eight statements will be discussed. These seem to portray a clear agreement or disagreement with a statement while other cases seem to be characterised by indecision on the part of the students. Kendall (1954), cited by Ogunniyi (1977:43) argues with respect to the conflict of goals that when subjects are asked to express their viewpoints on a subject matter, the extreme responses seem to be more stable and to reflect the intensity of belief than the middle or neutral responses.

The statements mostly associated with an exemplary teacher relate to such things as: effective lesson presentation, class control and management, classroom environment and interactions, management and use of teaching aids and materials, selection and presentation of content. Statements dealing with the effectiveness with which lesson materials are presented tend to dominate the most frequently stated characteristics of an exemplary teacher in this study. Though in a different kind of context, Yoder et. al. (1994) found that student teachers in Botswana considered instructional skills to be more important traits of "good teaching" than personal traits.

Student involvement in the learning process seems to be rated highly by the students involved in the present study. For instance, four of the top ten statements have to do with providing students opportunities to participate in the lesson. The statement requiring an exemplary teacher to encourage students to participate actively during the lesson had a mean score of 2.97. Another statement that had a mean score of 2.97 was that exemplary teachers should give home work that is related to what the students did in class and that the teacher should also make sure that such homework was marked. Two other statements which dealt with some sort of participation in the lesson, ranking 9th and 10th respectively were concerned with exemplary teachers encouraging students to plan and carryout experiments (M = 2.73) on the one hand and encouraging students to discuss their work in small groups (M = 2.70) on the other. It appears that students see themselves as active participants in the learning environment.

While students portray an exemplary teacher as the one who would create a learning environment in which the students would actively participate in the learning process and as such create their own knowledge, they do not see active participation as absolving them from memorising information for tests and examinations. It appears that though the students would want to be actively involved in the learning situation, that should be in so far as it helps them to acquire a body of knowledge necessary to carry them successfully through tests and examinations. For instance, the same students ranked the statement that an exemplary biology teacher should encourage memorisation for tests and examinations third highest (M = 2.92). Active participation in this sense would imply a lack of construction of meaning. This may not be unrelated to the use of practical work to clarify and confirm concepts and theories. If practical work is not portrayed as a dubitable enterprise but rather as "a rhetoric of conclusions", then the students cannot be expected to go beyond the given in that they do not consider themselves as constructors of knowledge but rather as consumers of readily available knowledge. This reflects a fundamental problem facing curriculum change in situations where the examinations maintain a stranglehold effect on the curriculum.

Students' perception of learning is a product of their experiences in the classroom as well as the cues received from their culture (Davis and Mason, 1989). Their notion of active participation mainly for the purpose of acquiring a body of knowledge has serious consequences for the classroom teacher in at least two ways. First, is the problem of how to encourage the students to take responsibility for their learning beyond mere reception of well tested facts, to seeing learning science as a continuous process of concept development characterised by reflection on the problem at hand, the methods of investigation and negotiation of meanings and consensus with other students. Second, is a problem of sharing meanings between the teacher and the learners about active involvement in the learning process for a constructivist teacher. While the teacher would expect the learners to be constructing their own knowledge in classroom activities, the learners are searching for proven facts that characterise the examination questions at any rate. Given such a situation, the possibility of meaningful learning seems to recede from the reach of students because their beliefs about learning which are not congruent with those of the teacher, and without this shared understanding, the students and the teacher are in two different worlds. As such, teaching strategies that hold promise for promoting construction of knowledge may prove to be less effective because the teachers and the learners hold divergent beliefs about teaching and learning and their separate roles in such endeavours.

Another statement ranked 6th by the students deals with effective lesson presentation. To the students, an exemplary biology teacher should provide appropriate and adequate materials for the lesson (M = 2.82). Of course, if students believe that they should be actively involved in the lesson, then the need for materials that are appropriate and conducive for such active participation are necessary. It is observed though (from one of the responses to the Student Participation Inventory), that students have a broad conception of 'active participation'. They tend to embrace discussions, experimentation and asking questions so that they could understand better. They rated 4th, the statement that an exemplary biology teacher should make sure that the students are always on task and not playing during the lesson (M = 2.87). It can be assumed that a classroom atmosphere characterised by students' active participation in various activities would promote the opportunities for knowledge construction. But the potential benefits of such an atmosphere cannot be realised in an atmosphere of chaos, and hence the importance of proper classroom management. Two statements dealing with classroom management were ranked 5th and 7th by the students. Next in the rank is the need for the teacher to get instructional materials ready before the lesson (M = 2.84) and also to write on the board regularly and clearly (M = 2.75). Off-task behaviour are likely to occur if the students are left unattended for a prolonged duration, e.g. the teacher going to fetch some apparatus that was not ready before the lesson. Of course, proper use of the chalkboard may go a long way into enhancing learning by providing a visual prompt to the students. It also ensures that the concepts represented are available for reference for a longer period of time. Also, an exemplary teacher should give verbal rewards for correct responses (M = 2.73).

It appears that statements dealing with management of the learning situation dominate the bottom end of the rank order. These are the statements that the students do not seem to agree with. The statement suggesting that an exemplary teacher should not provide girls and weaker students ample opportunities to participate in the lesson because they delay others (M = 1.14) was rated least. Considering that the rank values were from 1 to 3, then a mean score of 1.14 reflects a strong disagreement with the statement. The students' response to this statement seem to be the direct opposite to the statements in the top ten rankings which deal with students' participation in the learning process.

Students deem the ability of the teacher to allow everyone in the class, irrespective of sex and academic ability to participate in the lesson a desirable trait of an exemplary teacher. Closely related to this, and ranking a bit higher (M = 1.52), is that the teacher should not direct questions, only to students who are likely to answer them correctly. While directing questions to students even when they may not successfully answer them enables the teacher to determine the effectiveness of the teaching and learning strategies during the lesson, it exposes the learner to a period of vulnerability, of not knowing, and of exposing that ignorance. In making a response to such a question, the learner is taking a risk, the consequences of which can either be minimised or exacerbated by the way the teacher handles incorrect responses.

Students' responses, just like their questions, can be useful indicators of the cognitive gains the learners are making during the lesson and can be useful tools to determine the learners' 'zones of proximal development' (e.g. Vygotsky, 1978) in order to effectively afford the students the necessary cognitive apprenticeship, as well as aid the process of concept development. As such, ignoring students responses is not considered a desired trait of an exemplary teacher (M = 1.52). At least two problems could arise as a result of the teacher ignoring the students' responses. First, it could be used as a form of exerting authority by the teacher to indicate to the student that the response is wrong and not worth wasting time on. When used this way, ignoring students' responses can effectively inhibit their enthusiasm, depriving them the opportunity to negotiate ideas in their social setting. Second, it could be used to cover up the teachers' inability to isolate and develop the correct aspects (albeit at a rudimentary level) of the students' 'wrong' responses. This deprives the students an opportunity to build upon what they already know. It completely takes away the opportunities to conjecture and to test ones intuitions against those of peers - a process necessary for the social construction of knowledge. This marginalisation of opportunities to construct ones own knowledge, does not only dampen the students' spirit of active participation, but also sets the students vulnerable to the charybdis of rote learning. It is a form of symbolic violence (Tobin, 1996).

Prophet (1990) describes a situation in which a teacher ignored the students' incorrect responses until one student gave the response the teacher wanted. The teacher acknowledged the response and went on to something else. Such a situation, in which certain target students (especially the bright ones) are used by the teacher to set the rate of progress of the lesson (M = 1.27) is not considered to be a desired characteristic of an exemplary teacher. Students also do not regard allowing the class to answer teacher questions in a chorus to be exemplary behaviour (M = 1.23). Such chorus responses do not only belie the real level of conceptual understanding by the students, but also bedevil constructive learning since the teacher is likely to pick the correct response from the chorus and continue with little reference to the many incorrect responses in the choral answers which could have been used constructively to enhance meaningful learning.

Ausubel (1968) regards what the learner already knows to be important for meaningful learning to occur. The new information is considered to relate to the appropriate cognitive schemes already existing in the learner as a result of the learners' experiences as he/she interacts with the environment. Meaningful learning, therefore, occurs when the learner negotiates new meanings against the background of prior knowledge.

Students however, do not seem to concur that prior knowledge is necessary for learning to occur, or rather that their everyday life experiences at home form part of their prior experiences. They rate the statement that, exemplary teachers should relate what is taught to their experiences at home low (M = 1.50). This statement is perhaps misunderstood or may not be unrelated to the nature of school science that has for a long time alienated students'' experiences in the laboratories from the everyday experiences of the society in general and the students in particular: This is what Cobern, (1996) terms, "cognitive apartheid". This also may not be unrelated to the kind of socialisation the students get from the society which sees the schools as places where children acquire the education that liberate them from the poverty and deprivation of their rural pastoral lives as well as increase their chances of obtaining a white collar job. This suggests a disparity existing between the curriculum intent and students' expectations and consequently, an obstacle that may hamper their ability to solve real life problems that confront them daily.

4.5.0 Students' perceptions of their participation in biology lessons.

Construction of meaning is largely a matter of active participation in the learning process. Consequently, a learning situation that provides opportunities for the students to interact with the learning environment and make sense of their experiences is essential if construction of knowledge by the students is the desired end. It has been established earlier in this study that students regard active participation as an important feature of exemplary practice. Whether or not students get opportunities to participate in the learning process remains an important determinant of the extent to which they may be involved in the construction of knowledge. Table 11 shows the mean scores representing how students perceive their participation in exemplary biology lessons. The students rated the statements in terms of: 5 = always; 4 = frequently; 3 = sometimes; 2 = rarely; and 1 = never. The top ten statements have mean scores ranging from 3.92 to 4.26 and as such can be regarded as behaviours that occur frequently in exemplary lessons.

Table 11: Students' perceptions of their participation in exemplary biology lessons.

Statement	Mean	Rank
Tells us what should be able to do at the end of the lesson	4.26	1
The teacher makes sure that we all can see what he/she is showing	4.23	2
Everyone in the class is encouraged to talk	4.16	3
Everyone gets a good chance to talk	4.10	4
We discuss our results with the class and explain our answers*	4.05	5
We discuss the observations and agree on what to record	4.02	6
The teacher explains each step of the experiment*	4.00	7
Everyone in our group gets a chance to take part in the experiment	4.00	7
I participate in the discussions because everyone is free to talk	3.93	9
We ask questions when we do not understand	3.92	10
We help each other understand the task assigned to us	3.88	11
We learn a lot from each other	3.86	12
We are given enough time to solve problems raised in our group	3.77	13
I get a chance to handle and use the apparatus to do experiments	3.71	14
The teacher checks to see if a homework is done	3.70	15
Everyone in our group gets a chance to take part in the experiment	3.64	16
Teacher asks us to explain some steps during a demonstration.*	3.64	16
Asks questions that require us to recall facts from previous lesson*	3.53	18
Allows us to raise and discuss issues related to the topic	3.48	19
The bright pupils talk most of the time	3.31	20
Some pupils do not finish their homework	3.26	21
Only those who are good in English do a lot of talking	3.10	22
The teacher talks for a long time while we are listening silently	3.01	23
At the end of the lesson, the teacher gives us homework	2.96	24
The group decides how to carry out parts of the experiment*	2.95	25
Questions that challenge us to think about what we are doing*	2.94	26
Some pupils are asked to perform the demonstration to the class	2.82	27
We help each other finish the homework	2.81	28
I try to finish my homework before everyone else in the class	2.76	29
Brighter pupils always tell the group what to record	2.75	30
Some pupils never handle the apparatus and do the experiments	2.66	31
Some pupils climb on top of stools and tables in order to see well	2.66	31
Boys talk most of the time	2.50	33
Teacher allows us to discuss some topic related daily experiences*	2.36	34
Only the bright pupils get a chance to say their ideas	2.23	35
Boys get more chances to talk than girls	2.22	36
Some pupils sleep during the biology lesson	2.20	37
I never get a chance to talk	2.18	38
No pupil is ever asked to help the teacher do the demonstration	2.13	39
I do not want to talk because when I make a mistake, others laugh*	2.11	40
Boys lead the discussion while girls record the points agreed upon	2.11	40
Boys do the experiments while girls record the readings or results	2.09	42
We argue a lot and never agree on anything	2.01	43
We decide the experiments we want to do	2.00	44
Only the big boys help the teacher during a demonstration	1.99	45
We are allowed to copy each other's solution to the assignment	1.89	46
Only boys help the teacher do the demonstration	1.80	47
Boys tell the group what should be recorded	1.76	48

* Denotes a shortened statement (See appendix for full statement)

Exemplary teachers tend to tell the students the objectives of the lesson before proceeding with the lesson (M = 4.26). The chances that the students make more sense of their experiences during the lesson are better when they are aware of what they have to achieve. Thus construction of knowledge does not only require students to carry out instructional activities, but also requires them to relate their investigations with the broader ideas they are developing (Driver, et.al., 1994). Students taught by exemplary teachers are encouraged to talk during the lesson (M = 4.16) and actually they all get a good chance to talk during the lessons (M = 4.10), hence their learning environment affords them increased opportunities for interactions, questions, discussions and negotiation of meanings.

Group work in exemplary lessons seem to provide the students with opportunities to discuss their ideas with others and in the process, to learn that ideas do differ and that they can be enriched as they interact with one another (Gallagher, 1993). They get a chance to discuss their results with the whole class (M = 4.05) and defend their viewpoint with a view to adjust their ideas and accommodate ideas from others. Thus, they negotiate ideas in small groups and consensus in the whole class setting (Cohen, 1993).

Exemplary teachers tend to ensure that all the students get a chance to take part in the experiment by making it a point that each student has a role to play during the experiment (M = 4.00). Task specialisation when used in small group work promotes participation by all members of the group. Without task specialisation, group work may result in a few students doing all the hands-on activities and others passively drifting along without being engaged in any real hands-on experiences and sense-making from such experiences. It should however be noted that exemplary practice does not advocate for hands-on experiences for the sake of experience. Such experience should be embedded in a matrix of meaningful discourse with the problem to be tackled. Prior to the hands-on activity, students should think of the purpose for the activity. During the activity, students should critically consider their methods of conducting the activity, their methods of collecting the data and their methods of presenting it. In other words, they should critically reflect on the activity. If the concern for teaching and learning is the construction of knowledge by the student, then hands-on experiences should be done for a purpose and such a purpose, should be the sense the learner makes of the experience.

During demonstrations, exemplary teachers ensure that all students can see what the teacher is doing or showing (M = 4.23). They also tend to ensure that they share meanings with the students by explaining the reasons why they carry out certain steps in the demonstration (M = 4.00). This sharing of meanings is important since what the teacher may think he/she is demonstrating could be at variance with what the learners perceive as the purpose of the demonstration. Thus the interpretation of the demonstration is not likely to be obvious to the learner and as such the negotiation of meanings is essential for students to appreciate what the teacher wants the demonstration to accomplish (Millar, 1989).

A trend emerging from the bottom ten statements in the rank order, portrays no overt cases of gender domination in exemplary lessons. For instance, five of the ten statements reflect that boys do not: i) dictate to the group what should be recorded during the experiments (M = 1.76), ii) dominate helping the teacher during demonstrations (M = 1.80; 1.99), iii) do the experiments while girls record the results (M = 2.09) and iv) lead the discussions while the girls record the points agreed upon (M =2.99). Perhaps, this lack of overt gender domination in exemplary lessons is not unrelated to the fact that the disparity that existed in the performance of the boys and girls in the pre-test scores did not persist in the post-test scores of the subjects exposed to exemplary teaching and learning strategies. It seems that the use of exemplary teaching and learning materials reduced the social dominance of boys over girls. This may not be unrelated to the fact that exemplary learning materials were structured such that students were responsible for carrying out some part of the learning task. The roles were constantly changing so that there would be no monopoly of roles and hence of learning experiences. As such, both girls and boys had ample opportunities to participate. As a result the learning situation which was symbolically less violent to the girls was created. Also, Greenfield (1997) reports that girls who are exposed to learning situations which offer ample opportunities for all students to learn collaboratively, believe that they are equally as good science students as are boys. This positive self concept could have had salutary effects on the participation and achievement of girls in exemplary lessons.

4.5.1 Student's experiences in biology practical.

One of the limitations of survey questionnaires is that they are rather closed. The Student Participation Inventory contained two open-ended questions that students had to respond to. It was hoped that these would give a deeper understanding of the students' experiences and preferences in practical work. Table 12 gives a summary of the students' descriptions of their experiences in biology practical.

Table 12: Categories of students' experiences in biology practical work.

Category		Example	Non-exemplary (%)	Exemplary (%)
1	Enjoyable/ easy/ learn new things	Practical activities were nice, good and encouraging. And I leant a lot from them (Girl, 16 yrs).	5.9	23.3
2	Specific episodes	We were checking for starch in foods. Teacher gave us different types of food to test. We used iodine solution to check if starch was present. It was present in bread and mealie-meal (Girl, 19 yrs).	0.0	11.7
3	Useful skills, discussions and ideas/ enhances participation.	I like group discussions in biology because they help us to understand what we are taught (Boy, 16yrs)	3.9	8.3
4	Useful in the future.	...biology can help us a lot in the future. Others can become nurses etc.(Boy, 16yrs)	5.9	0.0
5	Aids understanding	I like practical activities because we can understand very easily and it is easy to remember answers (Girl, 18yrs)	13.7	21.7
6	Confirms what was taught.	...Practical help us to understand what the teacher was teaching and see whether it was true or not (Girl, 16yrs)	21.6	1.7
7	Practical needs care and accuracy.	Practical activities are good and they need a lot of concentration (Girl, 17yrs). Practical activities are to be carried out accurately (Boy, 18yrs)	2.0	3.3
8	Practical activities are difficult/scary/ boys do the practical tasks than girls	During practical work...sometimes I get bored because it is hard (Boy, 19yrs). ...boys always do the work than girls (Boy, 18yrs)	17.6	3.3
9	Opportunity to make noise/chat/ no experience with practical work.	We usually make a lot of noise and play with the apparatus during practical work (Boy, 16yrs)	3.9	0.0
10	Uncodeable/ blank	During practical activities, I got so many ideas of how to pass biology (Boy, 17yrs).	25.5	26.7

An examination of Table 12 indicates that apart from only two categories, category 7; 'practical needs care and accuracy' and category 10; 'uncodeable/blank', there are marked differences between the experiences of students in non-exemplary and exemplary lessons in all other categories. It appears that students in exemplary lessons find their practical work enjoyable, easy and feel they are learning a lot of new things more than their counterparts in non-exemplary lessons (i.e. 23.3% to 5.9%). Perhaps this is related to the fact that the students in the exemplary lessons remembered specific episodes from their biology practicals while those from non-exemplary lessons did not mention any specific episode they experienced in their lessons. White (1991) argues that one of the roles of practical work is to provide specific episodes to the learners. These are experiences that the students find perplexing and exciting and as such are not easily forgotten. The episodes that characterised exemplary practice serve to aid conserving memory as well as a rich source of personal motivation. This is aptly portrayed in the following excerpts from students relating their experiences in biology practical:

> The test for reducing sugar. We used Benedicts' solution for testing. When heated in a water bath it changes to orange (Boy, 18 years).

Another student asserts, with respect to the teacher's dissection of a rat to expose the digestive system and the food test that:

> It is sort of hard to operate animals and to experiment with food substances. But biology practicals are sort of interesting. For instance, we stretched out and measured the ileum of the rat. It was fifty centimetres, that long!(Male, 14yrs).

8.3% of the students in exemplary lessons compared to 3.9% in non-exemplary lessons report that practical work provides a forum for useful discussions and negotiation of ideas. It also affords the students opportunities to gain useful process skills as well as to participate in the lessons. Group discussions create a milieu in which students can evaluate their ideas against those of other members of the group. They can ask questions, make suggestions, put forth their different ideas and negotiate consensus. Perhaps for a change, their ideas get some audience and are treated as valuable contributions to the debate. The following statement sums this up:

> In biological practicals each and everyone's opinion is listened to. We are also allowed to work in groups when doing practical activities (Boy, 17yrs).

If the concern for teaching and learning is the deeper understanding of concepts, then practical work should not only provide the students with experiences but also provide opportunities for students to make sense of the experiences. 21.7% of the students in the exemplary group find biology practical as providing opportunities for deeper understanding of concepts while 13.7% in the non-exemplary group express the same view. Students in non-exemplary lessons also portray a positivist perspective of practical work. For instance, 21.6% of them believe that practical work serves to confirm theory while only 1.7% of students in exemplary lessons think so. Practical work used to confirm theory might fail to promote construction of knowledge because it may be carried out routinely without much reflection on the part of the students. On the contrary, practical work that is done to evince knowledge construction could provide opportunities for questions, discussions, negotiations and collaborative interpretations (Roth and Roychoudhury, 1994).

Given that students in non-exemplary lessons find practical activities less enjoyable, not providing enough useful skills and opportunities for discussions and generally as a means to confirm theory, it would not be surprising if they find biology practical difficult (17.6%) and hence engaged themselves in unproductive activities (3.9%) compared to 3.3% and 0% respectively in exemplary lessons. This confirms the data in Table 3 where 4% of class time was spent on non-productive activities.

Table 13: Categories (%) of students' reasons for preferring group discussions and practical work to demonstrations, lectures and blackboard notes.

Category		Example	Non-exemplary (%)	Exemplary (%)
1	We share ideas/opinions	...I can share my opinions with others and learn from them (Boy, 17yrs).	39.4	50.0
2	Lectures aid recall	I prefer lectures because they help us learn to listen and recall (Girl, 17yrs).	6.1	4.0
3	We understand more/ better.	...most of the time we understand better because we are free to say our feelings (Boy, 17yrs).	33.3	36.0
4	Understand what teacher teaches.	...in groups we are going to say our views and after that the teacher is going to help us...(Boy, 18yrs).	12.1	0.0
5	Good chance for chatting.	...we get a good chance of chatting and black board notes are tiring (Boy, 16yrs).	3.0	0.0
6	Improve self-concept.	...it gives us a chance to improve our self-esteem and to be free and too confident when presenting and also feel that we speak English well (Girl, 16yrs).	0.0	4.0
7	Uncodeable/ blank.	...because it can help us a lot (Boy, 18yrs).	6.1	6.0

The second and last open-ended question on the Student Participation Inventory required students to say whether they would prefer group discussions and practical activities to teacher demonstrations, lectures and blackboard notes. Table 13 above shows the categories of the students' reasons for their preferences between group discussions and practical activities on the one hand and teacher demonstrations, lectures and blackboard notes on the other.

Students' reasons for preferring group discussions and practical activities to teacher demonstrations, lectures and blackboard notes differ in four major ways in the exemplary and non-exemplary lessons. They differ in the extent to which students: i) consider practical activities as providing opportunities to share ideas and opinions; ii) perceive the role of the teacher in relation to knowledge acquisition; iii) view practical work as a time to chat and iv) view practical work as helping to build their self-esteem, confidence as well as their competence in the English language.

The idea that the students in exemplary lessons tend to view active participation as central to exemplary practice seems to transcend their responses in different contexts. While the students (as earlier reported) connote 'participation' only in terms of physical activities, it was not so clear whether or not such activities involved both the verbal and mental acquiescence. In Table 13, the results clearly indicate that mental and verbal activities are perceived by students as constituting active involvement in the lesson. 50% of the students in the exemplary lessons compared to 39.4% in non-exemplary lessons consider group discussions and practical activities to be providing them with opportunities to share ideas and opinions and as such creating an environment conducive to the construction of knowledge. Practical activities and discussions in exemplary lessons seem to compel them to think and to create knowledge for themselves. This confirms the findings by Hand, Treagust and Vance (1997) that students preferred constructivist teaching and learning approaches because they provided them with opportunities to think and as such become independent learners. These notions are communicated in these excerpts:

> I prefer group discussions because I have more chances of saying out my ideas. Group discussions help me to think rather than when the teacher spoon-feeds me by lecturing and increases the chances for me not to think (Girl, 16yrs).

> ...because in group discussions we have a lot of time to share ideas but when we have the teacher she always gives us the correct results (Boy, 16yrs).

The way students perceive the role of the teacher in group discussions and practical activities differs in the two groups. Students in the non-exemplary group seem to put more faith in the teacher as a source of knowledge than on their own practical activities. For example, 12.1% of students in this group refer to the teacher as either explaining the results, telling them whether they are right or wrong or discussing with the group. In this sense, meaning is not derived from the practical activity itself or the discussion that the group is engaged in but should come from the teacher. It is the teacher who should explain, discuss and tell the students the right information. It would appear that students in this category do not see themselves as information seekers, but rather as passive recipients of teacher transmitted knowledge.

Four percent of the students in non-exemplary lessons prefer group discussions and practical activities because they see it as time to engage in off-task behaviours. Carl Rogers (1983) in his theory of the self-concept argues that every student has the innate desire to grow, to perform optimally and to realise his/her full potential. Students who perceive group discussions as the time to chat seem to lack this desire. It seems they are not making the best use of the time. They probably fail to realise that ultimately learning does entail taking personal responsibility.

Students would only perform optimally if they believe they have the potential to influence their learning. For this reason, a positive self-concept is essential for the students to construct their own knowledge. Group discussions and practical activities are considered by students in exemplary lessons to provide ample opportunities to improve their self-concept (4.0%). This may be related to the feedback they get from their peers and consequently the interpretations they attach to such feedback.

4.5.2 Teachers' perceptions of the nature of, and constraints on practical work in biology lessons.

The teacher questionnaire was used to explore the nature of practical work in biology, the constraints encountered by biology teachers and the process skills that teachers strive to impart within the contexts of their teaching and learning environments. To reflect the nature of practical work, 20 biology teachers were asked to indicate the frequency of occurrence of the type of practical activity potrayed by the statements in their lessons. To explore the factors that affect practical work in biology and the teaching strategies used to help students develop process skills, the teachers were required to indicate whether or not the factor described by the statement was a satisfactory, not a satisfactory condition or a serious impediment to the nature of practical work in biology or the development of process skills by pupils.

Table 14: Mean scores for statements reflecting the nature of practical work in biology.

Statement	MS	Rank
A. Types of practical work in biology.		
Students required to make accurate measurements and observations.*	3.7	1
Practical work that requires students to use scientific apparatus correctly.	3.6	2
Practical work done to verify facts and principles.	3.5	3
Practical work done to illustrate theoretical principles.	3.4	4
Students presented with experiences that will make phenomena real.*	3.35	5
Student required to read, understand and carry out instructions.*	3.35	5
Students presented opportunities to acquire and use standard techniques.*	3.45	7
Demonstrations done to provide episodes to enhance long term memory.*	3.15	8
Problem solving experiments that are of interest to the students but which are not necessarily related to the theoretical work done in class.	2.35	9
Investigations that allow the students to identify, define, analyse the problem, and decide how to collect data, control variables and report.	2.2	10
B. Factors affecting practical work in biology.		
The teachers' competence to organise the practical work.*	2.74	1
Number of periods allotted for biology.	2.53	2
The heavy teaching loads of biology teachers.	2.45	3
Availability of funds to purchase laboratory equipment and supplies.	2.45	3
The amount of practical skills required from the learner in the final examinations.	2.35	5
Reliable supply and delivery of equipment and chemicals.	2.25	6
Laboratory equipment and chemicals available in the department.	2.2	7
Biology lessons time-tabled to be taught in regular classrooms.	2.2	7
The design of the laboratory.	2.0	9
The availability of lab. assistants to help in the preparation of practical work.*	2.0	9
Availability of laboratories.	1.85	11
Number of students for a laboratory class.	1.65	12
C. Development of process skills in practical work in biology.		
Make accurate observations and measurements.	2.65	1
Use scientific equipment correctly.	2.65	1
Develop safe working habits and to respond appropriately during accidents.	2.65	1
Use scientific equipment correctly and safely.	2.6	4
Collect accurate data and record them clearly.	2.55	5
Draw relevant conclusions from experimental data and observations.	2.5	6
Draw specimen to scale and label accurately.	2.45	7
Identify relevant variables to be controlled during the investigation.	2.35	8
Read and carry out instructions as expected.	2.2	9
Decide what data to collect and how to collect them.	2.2	9
Identify and analyse the problems to be investigated.	2.0	11
Communicate their findings and ideas clearly and logically in a variety of ways.	1.95	12
Decide the procedure to be followed, select apparatus and use them effectively during an investigation.	1.9	13
Evaluate the effects of the limitations of the experimental approach on the reliability of the data collected.	1.9	13

* Denotes a shortened statement (See appendix for full statement)

4.5.3 Types of practical work in biology lessons.

The teachers were asked to rate the practical work they used in terms of a 5-point scale: 5 = frequently used; 4 = used; 3 = occasionally used; 2 = rarely used and 1 = never used. An examination of Table 14 reveals that the teachers did not frequently use practical work in biology. The mean scores for the top three statements about the types of practical work teachers used in their lessons are 3.7, 3.6 and 3.5 respectively. These are nearest to option '4 = used'. The argument here is not whether or not teachers should involve their students in more practical work but rather that practical work should be used when it is the best option in so far as encouraging deeper understanding of concepts is concerned. When the same depth of understanding can be achieved through other less expensive, and perhaps less time consuming approaches, then those should be given priority.

This study has shown that the teachers in non-exemplary biology lessons: i) out-talk their students. It is doubtful whether teacher exposition enhances the students understanding of concepts and ideas any better than practical activities; and ii) that students themselves have been socialised to perceive practical work as a means to commit more information to memory as well as to clarify and confirm theory. Hence, the argument for more frequent use of practical activities becomes irrelevant if such activities do not help the students to make sense of their experiences.

It seems that practical work in biology lessons is dominated by activities that require students to: i) make accurate measurements and observations (M = 3.7); ii) use scientific apparatus correctly (M = 3.6) and iii) verify facts and principles (M =3.5).

Clearly, the nature of practical work done in biology classes does not seem to create opportunities for students to think critically, develop and evaluate their ideas, or to negotiate and reach consensus. In other words, the practical exercises seem to deny the students opportunities to create their own knowledge in the course of social interaction.

Practical work related to the students' interest (though not necessarily a part of the theoretical work) was rarely done (M = 2.35). The same applies to the practical work which could assist the students to identify, define, analyse the problem, decide how to collect data, control variables and report their own experiences (M = 2.2). Given the examination driven curriculum and the beliefs of teachers about teaching, it is hardly surprising that practical activities that have the potential to engage students in the process of active construction of knowledge are least entertained in the biology lessons observed in the study.

4.5.4 Factors affecting practical work in science.

The teachers were asked to state whether or not a statement about practical work represents a situation that is satisfactory (3), unsatisfactory (2) or that has serious impediment (1).

Teachers rated the following factors as satisfactory in so far as organising and carrying out practical work in biology lessons is concerned: i) their competence to organise and execute practical activities required in the syllabus (M = 2.74); ii) the number of periods allotted for biology (M = 2.53); iii) teaching loads of biology teachers (M = 2.45); and iv) the availability of funds to purchase laboratory equipment and supplies (M = 2.45).

They consider the following factors as constituting serious impediments to organising and carrying out practical work in their lessons: i) the number of students in a laboratory class (M = 1.65); ii) availability of laboratories (M = 1.85); iii) the availability of laboratory assistants to help in the preparation of practical work (M = 1.85).

Teacher competence is one of the factors that would to a great extent, determine how efficiently and effectively students get involved in meaningful practical activities. The teachers believe that they are competent to organise and execute practical work in biology. They also indicate that adequate time is allotted to biology and that their teaching loads are reasonable. But as reported earlier in this study, the teachers tend to involve pupils in practical work that only require the students to measure and observe accurately, use apparatus correctly and confirm theories. Perhaps, this reflects a much more rooted problem, that is, teachers' beliefs and perceptions of the nature of science. If teachers perceive science as a cumulative body of knowledge, then they are more likely to use teaching strategies that would help the students acquire this body of knowledge. On the other hand, if teachers perceive science as a consensus of the scientific community they are more likely to portray that in the strategies they use to help their students negotiate ideas and reach that consensus.

Large classes, shortage of laboratories in some schools and lack of laboratory assistants can be a serious impediment for teachers to involve their students in meaningful practical activities. Ogunniyi (1995) found that lack of trained laboratory assistants constituted a serious impediment to the full realisation of the learning outcomes in Botswana secondary schools. The need for skilled laboratory assistants seems critical in a situation where classes are large and laboratories are used continuously by different classes as is the case in the present study.

4.5.5 Development of process skills in biology practical work.

Process skills are needed by the students to carry out their investigations in biology. They are the tools that the students use to explore phenomena in order to adapt or acquire necessary process skills. The process skills in this regard become a means to an end; the end being the effectiveness with which such skills are used to construct knowledge.

The process skills that teachers believe they satisfactorily help the students to acquire are: i) making accurate observations and measurements (M = 2.65), ii) using scientific equipment correctly (M = 2.65) and iii) developing safe working habits and to responding appropriately during accidents (M = 2.65).

The teachers do not seem to be satisfied regarding extent to which they are able to help their students to: i) evaluate the effects of the limitations of the experimental approach on the reliability of the data (M = 1.9), ii) decide the procedure to be followed, select apparatus and use them effectively during an investigation (M = 1.9) and iii) communicate their findings and ideas clearly and logically in a variety of ways (M = 1.95).

There seems to be a strong relationship between the nature of practical work done in biology classrooms and the process skills teachers believe they are helping the students to develop. This might be related to the nature of the examination system and other forms of assessment used to evaluate learning. The examination system places a lot of emphasis on such skills that do not require the learner to think critically. For this reason, difficult for the teacher to justify putting the students through a process that requires them to think through the problems and come to a well reasoned conclusion. In fact, even at the university level, students' approaches to learning tend to be characterised by the use of mnemonics, committing facts and problem solving procedures to memory, and rote learning of principles for reproduction during tests and examinations (Linder, 1993; Leonard- McIntyre, Linder, Mashall and Nchodu, 1997) or simply apply the so-called Fatima's rules – a kind of school game employed by students to attain high grades in the examinations without understanding the course content (Aikenhead, 1997). The issue here is that even in their earlier schooling, students had little or no opportunity to make sense of the practical activities in science lessons. Otherwise, how does one get a deeper understanding of the concepts being studied if teachers could not satisfactorily get students to: i) critically reflect on their practical experiences in terms of deciding the approaches to problem to be solved in their laboratory lessons, ii) reflect on their experimental approaches and methods of collecting data, and iii) communicate their ideas and findings to others.

4.6.0 The relative effects of exposing teachers to an induction workshop on exemplary practice.

Teachers, whether pre-service or in-service, have their own conceptions of what it means to teach and learn. These preconceptions are the working models with which they interpret interaction episodes in the learning-teaching situations. The way the teacher teaches is influenced by his/her beliefs about teaching and learning. Also, his/her behaviours and actions therefore, are part of a process to achieve what is considered to constitute successful teaching and learning. For any teacher to embrace an innovative teaching style, he/she needs to accommodate that style within his/her perception of the process of teaching and learning. If this does not happen, any new notion about teaching and learning may assume a symbolically violent stance to him/her. In that case, the teacher is more likely to reject the new style of teaching. This is what prompted the need for an induction workshop in order to give teachers reason for their intended behaviours and actions.

Getting teachers to attend the induction workshop was met with some resentment by the teachers. They could not see why they need to attend a workshop in order to teach using a package that consisted of student workbooks and lesson plans. This resentment could be best explained in terms of the fact that the teachers are actually trained and have been teaching for sometime. In this sense, they considered themselves able to handle teaching well in terms of their training and experience.

Perhaps, this is manifest in their evaluation of the factors affecting practical work in science. Teachers did not see their ability to organise and carry out practical activities in biology lessons as an impediment to carrying out practical work. As such, they did not view teaching in line with the requirements of the exemplary practice as problematic.

During reflections on the initial lessons that the teachers taught, they seemed to be comfortable with the amount of talking they did during the lessons, their dominance, the role of practical work in confirming theory and group work as a means for managing limited resources in biology lessons. They seemed more concerned with whether or not they had communicated the appropriate content to the students and whether they had covered all the materials they needed to cover.

By the end of the induction period, the teachers appeared to have reconsidered their perception of teaching and learning in at least three ways: i) perception of their role in group work relative to student participation; ii) perception of students' abilities; and iii) perception of their roles and how such roles affect student participation and the process of learning.

4.6.1 Teachers' perception of group work.

When group work is used as a means for providing the students a conducive social environment in which they would construct their learning, then the need to ensure that the group members are actively involved in the learning process becomes important.

This involves making it possible for all the students in the group to experience phenomena, think about the experience and make sense of the experience. While the teachers initially viewed group work essentially in terms of making sure that inadequate supplies and equipment are shared by the groups and that each group was amply exposed to phenomena, their emphasis seemed to have shifted gradually towards ensuring that such an exposure also provided sufficient opportunities for discussions. In a sense, the focus was not on interaction per se, but the meanings and interpretations that the students attach to the experience gained in the process. The setting was succinctly put by a teacher. According to him:

> A small group in a science lesson is like any other social unit in any community and as such has its own dynamics. There are in it, leaders and servants, co-operators and competitors, the supportive and the not so supportive. Unless you make the servant play the role of the leader by providing a conducive environment for such a role, the servant will always remain servant. Similarly, if students who passively sit through practical activities are allowed to continue like that, they will remain passive (Teacher 1, induction workshop).

This realisation is actually in line with the task specialisation espoused in the exemplary practice. It appears that teachers took it for granted that practical activities in small group work inevitably engage students into active participation. This perception seemed to have gradually changed in the course of the induction workshop. By the end of the induction process teachers seemed to perceive small group dynamics differently. Reflecting on the nature of interactions in small co-operative groups in the lessons he taught before and during the early sessions of the induction workshop, this teacher acknowledges how differently he views small group dynamics.

> I am amazed to realise now, just how many students in small group work tend to be spectators. They will always look upon someone in the group to tell them what to do, or do the experiments for them. They believe in

> him/her for the correct and accurate execution of the procedure. They do not believe in themselves at all. I think making sure that students have good opportunities to carry out at least some part of the experiment and take part in the discussions thereafter, should be the central concern of any teaching strategy that utilises group work as part of the endeavour to enhance conceptual understanding and active participation in the learning process. For a long time I have lacked this insight (Teacher 2, induction workshop).

There seems to be a realisation by the teachers that active participation should involve students in a meaningful discourse with the learning environment. In a sense, a realisation that 'hands-on' activities do not necessarily mean 'minds-on' as well and that practical activities do not of necessity engender student participation. For this reason, a deliberate effort should be made to ensure that students get cognitively involved in the learning process and that they actually get the hands-on experiences that the practical activities make available to them.

4.6.2 Teachers' perceptions of student abilities.

One of the common things teachers would do was to read out instructions for the students. The reason given for this was that the students are not able to read instructions. One of the teachers remarked:

> They [students] need assurance that they are doing the right thing. If you read the instructions for them, at least they start working immediately and stop arguing about what to do. That gives them time to reflect about their findings rather than whether the procedure was right or wrong. I do not know whether to say it is the primary schools or the junior community secondary schools that did not prepare them well (Teacher 3, Induction workshop).

At least two issues emerge from this particular conception. First, is that this view condones the perpetuation of the culture of positivist approaches to teaching where there seems to be only one way of proceeding in solving a given problem. Such teaching does not allow for divergent interpretation of the problem at hand, which would in turn result in a number of different ways of solving the problem. Second, is the concern for the product at the expense of the process. It appears the teachers were concerned more with students having more time to reflect on the answer than on the process through which the answer was reached. Perhaps, the problem with this approach is that the students are likely to view the answer to be just as alien as the process of getting it. If students are to take responsibility for their own learning, then they should feel responsible for both the process and the product of their investigations.

While this statement seemed to have some support from the teachers at the beginning of the workshop, there seemed to be a marked departure from it at the end of the workshop. Teachers rather felt that the students bring into the learning situation a wide range of prior experience and this existing knowledge actually influences what the learners would learn. Students are likely to interpret the results in line with their already existing knowledge and if they are to appreciate the results of their experiments, the disparity between what they take the instructions to require and what the teacher intends to them to require should be resolved. As such reading out instructions for the students does not resolve this disparity. For this reason, the students need to read, discuss and agree on what they should do in their groups. The teachers views regarding this idea seem to have gradually changed from a rather positivist perspective to a more interpretive one. This argument is portrayed in this statement which was made by a teacher towards the end of the induction workshop:

> It is important for the students to make sense of the instructions themselves. The teacher cannot necessarily be relegated to the back seat. He/she should be available to give the students insight where necessary, but should not be telling them how to go about executing their instructions. A concern for personal construction of knowledge is a concern for individual differences and a wide range of prior experiences. So each student is likely to interpret the instructions in a way that is likely to be slightly different from the next student - they need to discuss their procedure (Teacher 4, induction workshop).

4.6.3 The role of the teacher and its effects on the roles of the learners.

Teachers justified their verbose interactions with students in terms of the unwillingness on the part of the students to think and participate in discussions during the lessons. The teachers felt that if they ask thought-provoking questions, they end up answering the questions themselves. One teacher remarked " I always get very bored - I hate answering my own questions" (Teacher 2, induction workshop). Perhaps, this explains the reason why an overwhelming majority of all the questions teachers ask during science lessons are factual (e.g. Rammiki, 1991; Ogunniyi and Ramorogo, 1994).

The teachers however, seemed to have changed their perception of this situation. Their perceptions seemed to move away from viewing students as the ones who are lazy and unwilling to think to viewing their teaching approaches as the ones that influence student behaviour. The following statement reflects how one teacher receded into expository teaching styles when she started teaching after her teacher training:

> When I first joined this school, I used to incorporate a lot of practical activities in my teaching. With time I realised that other teachers were actually not doing this and the students were not actually interested in all that except the right answer. Basically, they did not see the importance of experiential knowledge. So, I ended up doing what was necessary to

> get them through their examinations and after all that is all that counts - get your students to pass exams and you are instantly a 'good' teacher. No one cares whether they have acquired any practical skills or experiences at all (Teacher 3, induction workshop).

The argument here is that the students do not seem to participate because the teachers have certain beliefs about what constitutes worthwhile knowledge and how this knowledge can be communicated to the students who in turn learn how to acquire such knowledge. In this sense, it is the teachers who dictate what should be learnt and how it should be learnt. This teacher sums it up in these words:

> Just walk to a group, which seemed to have been progressing well and stand silently and watch what they are doing. That is when the students would start saying 'Hey, don't do that, hey don't add that and so on'. The mere presence of a teacher unconsciously evokes all that feeling of submission and uncertainty because we have, for a long-time, potrayed ourselves as authority figures in the classrooms (Teacher 5, induction workshop).

This teacher is confirming the practices in the traditional classroom cultures where the teacher is seen to be the source of worthwhile knowledge and authority. Perhaps, more interestingly the teacher seems to reflect that after the induction workshop, she 'hears' the students and 'sees' their actions differently.

Teachers are also seen as communicating their intentions about what the students should learn and how they should learn it in the nature of their questions. This teacher, after the induction workshop had this to say about the nature of questions the teachers tend to ask in traditional classroom cultures and how such questions dictate the nature of learning that would occur:

> Mostly, when you teach them, you do not ask them questions that encourage them to construct knowledge - they are so used to questions that require recall. As such, they only commit knowledge to memory for tests and examinations - which is why they will always want a lot of reading time to read for tests (Teacher 1, induction workshop).

The nature of questions the teachers ask their students may be good indicators of what teachers believe is worthwhile knowledge. In this sense, teachers would ask factual questions because that is what it takes to pass the predominantly factual questions in tests and examinations. It would not be surprising then, that the students perceive memorisation as an important component of learning if the forms of assessment they are exposed to requires them to reproduce facts.

It appeared that at the end of the induction workshop, the teachers were actually aware of how their beliefs systems and interaction behaviours in teaching and learning would affect the way the students interpret these cues in the learning situation.

4.7.0 The classroom environment in biology lessons.

Table 15 below shows the mean scores for satisfaction, friction, competitiveness, difficulty and cohesiveness in biology lessons. Considering that the two treatment groups that did significantly better than the control group are the co-operative and the competitive ones, the overall classroom environment in exemplary classes comprised only of responses from these two groups.

The overall actual classroom environment in exemplary lessons is characterised by satisfaction (M =2.68) and difficulty (M = 2.49). This finding seems to pose a dialectical problem in that difficulty is not normally associated with significant gains in achievement or satisfaction. The argument here is not whether or not the students' experiences in biology lessons should not involve some element of difficulty, but rather what the nature of the difficulty reported here is, and how it could have contributed to cognitive gains in exemplary lessons. This is important because the intervention used here was not primarily aimed at changing the difficulty aspect of the students' experiences but rather to engage the students in a process of knowledge construction. If during this engagement, the students perceived some difficulty, how did this difficulty translate into cognitive benefits?

Table 15: Mean scores for the satisfaction, friction, competitiveness, difficulty and cohesiveness in the actual and preferred environments in exemplary lessons.

Variable	**Mean**	**SD**	**N**
Actual classroom environment			
Friction	2.23	0.97	552
Cohesion	2.43	0.89	552
Competition	2.43	0.90	552
Difficulty	2.49	0.86	552
Satisfaction	2.68	0.72	552
Preferred classroom environment			
Competition	1.38	0.78	558
Difficulty	1.47	0.84	558
Friction	1.74	0.96	558
Cohesion	2.78	0.62	558
Satisfaction	2.90	0.43	558

4.7.1 Difficulty, satisfaction and enhanced achievement: contradictory or complementary factors?

A thematic analysis of the students' utterances during biology lessons in exemplary classes may provide clues to this question. At least three issues can be identified which characterise the students' notion of difficulty. In the first instance, each student had to have a role to play or rather a part to perform in practical activities. Those students who had all along been coasting passively in practical activities had to be seen taking part in the learning process. It is at this time that their inadequacies are exposed while at the same time they carry the responsibility of doing the right thing for the group. The following excerpt exemplifies this. This took place in a practical activity in which the students were testing some solutions for starch, reducing sugars, proteins and fats. The students in this group had just finished testing a solution for starch. A group member (apparently a slow learner) was now performing the test for reducing sugars.

B_1 Now we are testing with Benedicts' solution [Pause].

B_2 Okay, put a little of that [Pointing to Benedict's solution][B_1 adds a drop of iodine solution]. Hey shake it first. Put it back and shake. [He puts the test-tube back into the rack].

B_3 Why has it come back to its original colour? [The brown colour of iodine cleared as it diffused into the solution]

G_1 What are we expecting? [Pause] No, you did not add Benedict's solution.

B_3 Okay, remove everything and start afresh [They threw away the solution].

B_1 Oh! We added iodine solution. I was trying to add Benedicts' and I added iodine. [He now puts a few drops of Benedicts, shakes the solution a bit and heats the mixture gently.]

G_1 Oh! Its changing - reducing sugars are present. It should turn to orange.

B_1 Ugh! I was quite scarred, thinking the glass will break when I heated the solution.

B_2 Its Pyrex man!

The students in this group end up getting the correct result. This however, was not an easy task. It was blended with disappointment, uncertainty, mistakes, reflections on the approaches used and the results thereof, negotiations of meaning and consensus and of course, fear. This constituted difficulty in the sense that students do not usually construct their knowledge this way. They usually acquire most of their knowledge through teacher exposition and only confirm it through practical work. Secondly, the students were taken beyond their zones of proximal development. In this excerpt, B_2 and B_3 appear to have taken the role of more knowledgeable peers and in that sense had to conjecture and test their intuitions during the learning process. For instance, they are puzzled that the solution does not change colour. It is not clear what the pupil expected but he/she was able to reflect and realise that iodine was used instead of Benedicts' solution. At the same time, these pupils kept on scaffolding B_1 who was actually performing the experiment. Thirdly, the pupils thrived and were successful in constructing their own knowledge. A student remarked 'Oh! Its changing - reducing sugars are present...' when a successful solution was ultimately achieved after a meaningful discourse with the problem.

The success achieved in this process carries with it an element of satisfaction. Perhaps most important in this whole process is the fact that the students have successfully created their own knowledge. Also, the satisfaction and successful achievement of results seem to give the students a better perception of themselves. Thus they tend to have a more positive self-concept. Thus, from this statement 'Ugh! I was quite scarred, thinking the glass will break when I heated the solution', it may be concluded that this student believes more in himself now than he did before. Hence, the significant achievement by the pupils in these exemplary lessons could be explained in part by their success, the satisfaction gained after a successful attempt and the positive self-concept they formed of themselves during the learning process.

4.7.2 Preferred classroom environment.

The students prefer classrooms that are characterised more by satisfaction (M =2.90) and cohesion (M = 2.78) than by competition (M = 1.38). Considering that 3 was given for 'yes' and 1 for 'no', mean scores of 2.90 and 2.78 respectively reflect very strong agreement. Of course, when viewed in line with earlier findings (Table 11) in this study, it makes sense for students to prefer a classroom environment that is more cohesive and satisfactory because it provides opportunities for sharing ideas and opinions. Perhaps, this could be viewed from a functionalist perspective of education, where one of the manifest functions of education is that of cultural transmission of values (Haralambos and Holborn, 1995; Henslin, 1995; Macionis, 1995). The fact that the students prefer classrooms that are in the main co-operative could be evolving from the societal orientations to socialise the learners to co-operate in order to achieve common goals.

Competition is not perceived as a desirable aspect of the preferred classroom environment. Perhaps this is not unrelated to the inherent nature of competition that for one to be successful, the other should not do so well. The cultural deprivation theory asserts that those who would not be successful in this case are those whose subcultures did not socialise them for competition and in which case, the female students are likely to be hard hit because they are socialised to be subservient to the males. As such, cohesion is preferred because instead of exacerbating the limitations of the already deprived subcultures, it turns their weaknesses into opportunities to explore situations beyond their zones of proximal development; a situation best described in terms of Bourdieu's cultural capital theory. According to this theory, the culture of the dominant class is not in any way superior to that of the less dominant classes. It is the educational system that is at fault because it systematically promotes the dominant culture and devalues the knowledge and skills of the less dominant culture (Haralambos and Holborn, 1995).

4.8.0 Classroom discourse: beyond exposition?

Discourse in the classroom can broadly be viewed in terms of teacher-pupil talk and pupil-pupil talk. The former has been extensively researched in Botswana (e.g. Prophet and Rowell, 1990, 1993; Hilsdon, 1993 and Ogunniyi and Ramorogo, 1994). There is however, a dearth of studies dealing with the latter. A socio-linguistic approach to discourse analysis was carried out to explore the process of knowledge construction in small co-operative groups in biology lessons.

One of the dominant features characterising the co-operative and competitive learning strategies used in this study is the within group discourse. This feature was not so characteristic of the individualistic and the true control groups. Considering that the individualistic group used the same exemplary package used in the co-operative and competitive groups, and yet the achievement of the students in this group was not significantly different from that of the students in the true control group, it could be argued that provision of practical activities alone is not a sufficient condition for construction of meanings by the students. Students need opportunities to make sense of their experiences. Hence, clues explaining the significant achievement in the co-operative and competitive groups could lie within the discourse that is allowed the students in small group activities.

4.8.1 The nature of student discourse in small groups.

Discourse in small group activities is characterised by statements, questions, responses to questions, instructions, orders or directions, arguments, requests, non-task related talk and the use of both the English language and Setswana from time to time, just to mention a few. It is amidst these utterances that the students are expected to enter a meaningful discourse with the learning situation and in the process to evaluate, modify or even abandon their ideas in the light of those of their peers and the scientific community.

The students' questions, statements, responses to questions from others and the nature of their arguments can serve as useful indicators of their conceptual development during the learning process. For this reason, these will be the focus of analysis of students' discourse in small group activities.

4.8.2 Nature of students' questions.

Student's questions appear to differ with their familiarity with the learning task. In unfamiliar situations, they seem to ask more procedural questions than thought-provoking questions. The following excerpt was recorded when the group was testing food samples for starch. The procedure is a little different from the usual one where they only put a drop of iodine on the food sample and observe the colour.

G_2 Okay, I have maize-meal (mealie-meal), sorghum meal and flour.

B_1 Where is the test-tube holder?

G_3 Please, look at this. Are we adding this 10 cm^3 here [pointing to the test-tube with mealie-meal] or in the other clean test-tube?

B_1 No! here [pointing to the test-tube with mealie-meal]. Then you add a little bit of water.

G_4 How many minutes do we need?

G_3 I think it is five minutes.

G_5 What is that - sugar? And that - maize-meal?

G_4 Then we pour water into each of the test tubes.

G_5 How much water?

G_4 10 cm^3

G_5 How much water?

B_1 A bit of water.

While students managed to make progress with their experiments, the questions did not seem to pose cognitive challenges to the students. The students seemed to religiously follow the instructions in order to get the desired results. In this case, the students' questions seemed to be rather factual and hence the responses to them did not involve anything more than short phrases for answers.

Simpler and familiar learning tasks however, seemed to attract a different set of questions from the students. In the following excerpt, the students were testing four different colourless solutions for the presence of starch by adding a few drops of iodine to the solution and observing the colour change.

G_1 The unlabelled one is D OK! The first one has not changed.

G_2 How many minutes should it take before we can say it has changed?

G_1 Which one has changed?

B_1 All! Or were they all like this?

G_2 Wait! In each test-tube, what was there - colourless solutions?

B_1 Yes then all of them have changed to brown.

B_2 No! We have to look at the colour of iodine. You see, bread has starch and when you add iodine to it, iodine turns to blue-black. So you do not look at the colour of bread but of iodine when it reacts with the food sample.

B_3 Solution C has starch. Iodine turned blue-black.

B_1 But I really think they have all changed. The first one has become lighter.

B_2 These were colourless but different solutions. When we added iodine, they assumed the colour of iodine except C, which reacted with iodine to produce a blue-black colour.

B_1 You cannot write 'no colour change' because they have changed yellow.

B_2 No, that is the colour of iodine, so iodine has not changed colour so "no colour change'.

B_1 But iodine has changed to a lighter colour.

B_2 Okay, write in capitals in your workbook - 'iodine has changed to a lighter colour'.

B_1 [Writes 'No colour change']

What seemed to be simple questions in this excerpt, 'How many minutes should it take before we can say it has changed' and 'which one has changed' triggered a whole debate on the conception of change. Factual questions like these in the unfamiliar situations were answered with very brief factual answers. In a familiar situation however, the pupils perilously account for change from their own interpretations about their concept of change.

It is clear that both students are actually correct. It should be expected that when iodine is added even to a clear solution, it should change in some way. In the absence of any substantial chemical reaction, it should at least be diluted. This seems to be the point that B_1 is trying to articulate. The student B_2 however, in the context of testing food samples for starch using iodine solution does not accept the concept of diluting iodine as constituting colour change. This does not suggest that if this student would add a brown liquid to a clear solution in a different setting, he/she would not observe that the brown liquid has changed to a lighter shade. The context in this sense seems to be an important determinant of what the students perceive as worthwhile knowledge. Perhaps, Marx Weber's method (Henslin, 1995) of the *verstehen* becomes applicable here in the sense that to understand the subjective meanings of the participants, one needs to place him/herself in their shoes.

4.8.3 Language, accountability and social control.

Small group talk is also characterised by arguments. It is mainly during these arguments that the students put forward their ideas and receive ideas from others. This is not a simple exercise where one simply shares ideas and others receive them. Ideas seem to be structured in such a way as to enhance their chances of being accepted by other members of the group. The students use a number of strategies in the rhetorical organisation of their language. These seem to include eliminating conditions that make their arguments vulnerable to counter arguments, the use of sarcasm, discrediting the source of rival arguments, substantiating, lobbying for support and bringing in new supporting evidence or arguments. The last part of the excerpt above exemplifies the use of sarcasm to discourage alternative arguments. This is how it goes:

B_2 No, that is the colour of iodine, so iodine has not changed colour so "no colour change'.

B_1 But iodine has changed to a lighter colour.

B_2 Okay, write in capitals in your workbook - 'iodine has changed to a lighter colour'.

B_1 [Writes 'No colour change']

Clearly, the argument that iodine has changed colour because it is now more dilute is a serious counter argument for the 'no colour change' idea put forward by B_2 but it seems to be easily brushed aside when the student sarcastically tells the other student to write it in capitals. Without further argument or questions, student B_1 gives up and writes what B_2 believes to be correct. It is doubtful whether student B_1 had given up his idea for the alternative one. Rather he seems to have interpreted the language used from the cues of his own socialisation. Thus, in spite of a learning environment that is conducive to discussion and negotiation of meanings, the way the students use and interpret the language in small group discourse is not free from the dominance that exists in the larger social setting of the classroom. In other words, students attach meanings to actions according to the norms of the society. For instance, when a teacher asks, "Is that thing on the floor a piece of paper?" Instead of the students responding by saying "Yes, it is", they would probably pick the paper and throw it into the rubbish bin. In this way they are interpreting the teacher's question within the context of the norms of their micro-society: the classroom.

The students also structure and use the language in such a way that it increases their accountability for their ideas as such making them difficult to rebut. The following excerpt perhaps, exemplifies this. It came from a lesson in which students were constructing food chains in small groups.

G_1 Does a lion eat a donkey?

B_1 Yes, a donkey is meat. A lion is a carnivore.

B_2 But it can't kill a donkey. The donkey finds a tree, puts its head amongst the branches so that the lion does not bite its neck and kicks the lion [laughter].

G_2 Why don't we say donkey eats grass, may be a lion does not eat a donkey after all.

B_1 But it is meat. Suppose it is already dead, would the lion still not eat it?

B_2 It will.

B_1 So, "lion eats a donkey" is okay.

The student B_1 in this case uses a number of overt strategies to ensure that the group adopts his concept of a 'lion eating a donkey' in the food chain. He eliminates the idea that the lion cannot kill a donkey, in this case, not by trying to show that the lion can indeed kill a donkey, but by suggesting a situation where the donkey would be dead already. He/she also ignores the new suggestion that would be less problematic in this case, 'donkey eats grass' and the uncertainty expressed thereof, and maintains that as long as the donkey would be meat, a lion as a carnivore should eat the donkey.

4.8.4 Language and construction of knowledge: beyond tacit information.

The students use language to communicate their ideas to others and to make sense of their learning experiences. Viewed from this perspective, language becomes an important determinant of what can be learnt meaningfully because it determines the extent to which the learners may convey their ideas for others to understand.

Language switching between English and Setswana in biology classrooms is a common phenomenon though officially, the students are expected to learn their science in English. However, there were classes in which students communicated predominantly in English and those in which students communicated predominantly in Setswana in their small groups. Moje (1995) observes that language in classrooms can be controlled and used to maintain classroom identity. In other words, teachers may use the elite language of science to maintain some degree of identity with the scientific community. Likewise, students who wish to be successful might want to adopt this language as a form of identity with the teacher and the class community. Some students however, may not want to be part of this dominant culture and hence may reject it in order to identify with other cultures and as such remain alienated from the dominant classroom community. It appeared that among the exemplary teachers, some were quite flexible with the language they used throughout the lessons. Such teachers would use both Setswana and English as they taught. Students of such teachers seem to show an increased tendency to freely converse in Setswana. An analysis of discourse in small groups in the exemplary classes where the dominant medium of communication is English shows some contrast between groups consisting mainly of fast learners and those consisting mainly of slow learners. Though the students were not deliberately divided into groups of fast and slow learners, the trends emerging from these groups were worthy of consideration. The following excerpts dealing with how plants feed reflect this contrast quite vividly:

G_1 How do plants feed?

G_2 They use the food they manufacture and nutrients from the soil.

B_1 They manufacture food through photosynthesis

G_3 They absorb nutrients from the soil

B_1 They absorb light through their leaves to manufacture their food

B_2 They need water and mineral salts to make food

G_4 The plants absorb nutrients from the soil. These nutrients and water would be transported to the leaves and then..Hmm!

G_2 Remember this space is small

G_4 The nutrients would be transported to the leaves to manufacture..Hmm!

B_2 Are these nutrients the ones that are used to produce food?

G_4 Yes

G_1 Like what?

G_4 Like starch.

G_2 No. Starch is produced through photosynthesis [silence].

G_2 May be the nutrients from the soil are used to build plant tissue and not to manufacture food.

The following excerpt comes from a group that is predominantly slow learners. They are tackling the same problem with the fast learner group.

G_1 Do trees feed?

B_1 Trees drink water from the soil [pause]. Let's write [pause]. They drink surface water [they write it down].

B_2 Hey man! I have no pencil.

B_3 Are you saying you have a pencil?

Fast learners on the one hand appear to explore a considerable number of alternatives to the problem before they reach consensus. In this particular dialogue, the first response by G_2 could have been considered to be adequate but the students continued to explore other possible responses to the problem. It also seems that each student in the group wants to contribute something to the debate. Hence, their discussions tend to be on-task for a much longer duration. Slow learners on the other hand, seem to be satisfied with brief responses particularly if they come from the student considered to be a more capable learner. It appears that most of the students in such a group are happy to coast along with the group without making any significant contributions to the debate. Their discussions also tend to be on-task for much shorter periods of time.

Students in the group that consists predominantly of fast learners also tend to notice discrepant events and explanations and use their existing knowledge effectively in an attempt to resolve such discrepancies. As such they tend to be more successful in making informed guesses in unfamiliar situations. The following vignette comes from a lesson in which the students were observing teeth from various skulls of mammals. This particular group was observing a jaw from a donkey. They noticed what looked like canines and this conversation ensued.

G_1 Ah! Look at the canines. What does it use them for?

G_2 May be for fighting [laughter][spell of silence].

G_3 But look at their size compared to the incisors, they are too small to be useful in the presence of incisors.

G_4 Yes, but why are they there?

G_3 May be they are wisdom canines, or premature teeth. Real donkeys do not have canines.

At the end of this conversation, the students were still not sure of what to call these "teeth" but they were quite convinced that these were not canines. They tend to use their knowledge about the types of teeth and the relationship between the animal's diet and the dentition well to suggest that these "teeth" are not canines in terms of what they expect in terms of size and function of the teeth, their knowledge of the diet of the donkey as well as their everyday experiences with donkeys, that they do not have canines.

4.8.5 Language and social reproduction.

An analysis of utterances in groups in which students spontaneously converse in English and in Setswana respectively, suggests that students who readily use English as a medium of interaction seem to i) discuss ideas to a greater depth; and ii) show a greater understanding of the concepts involved. Their counterparts on the other hand: i) appear not to go into much depth discussing their concepts; ii) tend to digress into chatting and humour; iii) very often, pose arguments which are variegated with folklore and non-task related talk and iv) bring into the discussion their everyday experiences.

Another vignette comes from a group that spontaneously conversed in English. The group was concerned about how different organisms feed. The case in point is how a housefly feeds:

G_1 A housefly can feed on solid food too.

G_2 How? It has no teeth.

G_1 No, it spits saliva on the food and the food dissolves and the fly sucks it in.

B_1 Do you mean saliva only can dissolve food?

B_2 It must be a lot of saliva and the fly must really sit for a long time for enough food to dissolve.

G_1 Ah! The fly is small, it does not need a lot of food anyway.

B_2 That is what I mean, its saliva should be so little that it dries up before anything dissolves.

G_3 Hmm! There must be something in it to help it breakdown food quickly.

B_1 Do you mean teeth? [Laughter].

G_3 No say...like enzyme?

G_1 Yes, like our saliva. Saliva only makes the food moist and the enzymes dissolve it.

The following vignette comes from a group that spontaneously converses in Setswana. The students are dealing with the same concept of feeding and they too are discussing how houseflies feed.

B_1 They feed on puss from wounds, our food, human excreta, hmm! Do flies drink water?

B_2 They suck with their long mouth, what do they call it?

G_1 Probo.., check in the workbook.

G_2 Proboscis.

B_3 Flies are funny. They never feed without excreting. They sit on your food and leave their excreta.

G_1 That is why they spread diseases. We eat their excreta, hmm!

B_4 That is not true, we would all be dead. Imagine how many flies fall into the milk, water and sit on the food at cattle posts and rural areas, but people are still healthy [laughter].

It appears that the students who spontaneously discuss their ideas in English are more likely to follow their discussion to a logical end than their counterparts who used Setswana in their discussions. An analysis of discourse in the groups that spontaneously used English tends to indicate that the students actually make more sense of the concepts discussed, and are able to go beyond the information given more than those who use Setswana. This phenomenon may not be unrelated to the fact that a lot of people in Botswana still consider anything that has colonial overtones as superior or desirable. For instance, it is not uncommon to find a beautiful child likened to a white (English) person; a brilliant child described in terms that connote English superiority or a perfume with as sweet smell described as smelling "English". As a result, students who seek social approval would identify with this notion of superiority, initially by using the English language and subsequently by showing a higher mastery goal orientation. A mastery goal orientation relates positively to increased self-confidence and the use of learning strategies that enhance meaningful learning (Ames and Archer, 1988; Graham and Golan, 1991; Meece and Jones, 1996).

Consequently, while Setswana as a language may not have a lot of words that would be equivalent descriptives of a lot of concepts in science, not enough seems to have been done to explore the potential of using it as a medium of instruction. The few cases where science concepts were communicated in Setswana belie the potential to which Setswana can be used to communicate science concepts. For instance, The metaphoric nature of the Setswana language exemplifies this phenomenon. Ramorogo (1992; 1995) cites the use of the word "moroto" (literally 'urine') to refer to semen in agriculture as one of the possible reasons why students who responded to a questionnaire in Setswana did not reflect an understanding of the particulate nature of genetic inheritance. As Thornton (1988) suggests, much of science has been developed in the western world, as such, its language and concepts are consonant with such languages. Such an observation, however, should not cloud the fact that as yet, it appears that not enough has been done to explore ways of exploiting Setswana as a medium of instruction in science.

Also, the fact that English is the official instructional language from the fifth year of schooling may contribute to the students viewing Setswana as inferior and relegating it to informal discussions. As Rollnick and Rutherford (1996) note, this language dualism may result it the alienation of the second language learner. They observe that in Africa there is a language for school and a language for home. The implication of this is that, if English is considered by the students as 'a language for school', then the students are likely to take their learning more seriously when it is the instructional language. Students who are alienated because of their lack of competence in the English language may demonstrate work-avoidant goal orientation. Students who display work avoidant behaviour want to complete the assigned tasks without working sufficiently hard (Meece and Jones, 1996). Perhaps, this may explain why those students who conversed in Setswana did not seem to reflect a deeper conceptual understanding of the issues at stake.

Beyond the view that Setswana cannot accommodate scientific concepts, the findings may suggest a broader picture of how students learn science. This embraces the realisation that students bring into the biology learning situation their worldviews which are not necessarily consonant with the scientific worldview. Of course, students use language to represent reality to themselves. As a result, learning biology involves learning both the concepts of biology and the language through which such concepts are presented. As such, if teaching does not take cognisance of both the students' worldviews and their language, the result could be that the students may actually hold conflicting ideas about phenomena. Students may hold such conflicting ideas without showing any cognitive dissonance. This is what Jegede (1995) refers to as collateral learning or what Ogunniyi (1988) calls harmonious dualism. Perhaps, the difference observed when students discuss their ideas in English and Setswana respectively suggests a case of collateral learning in which the students would compartmentalize knowledge in their long term memory and draw on appropriate knowledge for strategic use in either the English (Western) or Setswana (Traditional) environments.

It also appears that students who would spontaneously speak Setswana in their groups bring into the discussions a lot of folklore and their everyday experiences. From a costructivist perspective, students' perceptions of phenomena are important determinants of what they may learn. When teachers know the students' perceptions of a given phenomenon, it is reasonable to believe that they might structure their teaching such that it helps the students to appreciate the scientific worldview. For instance, while it may not seem problematic to the teacher to perceive how a housefly would spread diseases, it seems to be problematic to student B_4. According to him, 'we would all be dead' because flies sit on the food and fall into milk and water all the time. He has seen this happen so many times and he has not had cause to believe that flies transmit diseases. As a result, this student may (i) reject the scientific explanation and stick to his worldview; (ii) accept the scientific explanation and use it in the appropriate contexts while keeping his worldview for other contexts or (iii) relinquish his worldview for the scientific explanation. While there is no single way of teaching that would guarantee that students would relinquish their conceptions of the world for the scientifically accepted views, it is realistic to expect greater levels of success in this endeavour if teaching is geared towards modifying the students' alternative conceptions than when it is not. Perhaps, the students would be better placed to appreciate the scientific worldview if their prior ideas are taken aboard during the teaching-learning process. As such, the notion of a 'four-eyed fish' (Ogawa, 1996) which swims in the river with the lower part of its eyes looking into the water and the upper part of the eye looking above the water into the air seems a reasonable metaphor to adopt in this endeavour. In that case, the teaching of biology should also involve creating the students' awareness of their own views of the world.

The issue arising as a result of this finding is the realisation that the English language when used as a language of instruction creates problems for the learner. Learners who are not proficient in the language of instruction find it difficult to comprehend what they have to learn and as well as express and articulate their ideas in the English language. Perhaps, this is why students who may not be feeling quite comfortable would readily converse in Setswana in their groups. Perhaps, more profound, is the fact that the students seem to reveal more of their worldviews when discussing their ideas in Setswana than in English. If teaching is concerned with using the students' own ideas to facilitate deeper understanding of concepts in science, it might be realistic to be flexible about the discourse language in small groups. Of course, this finding has serious implications for teaching and learning. For instance, should science be taught in Setswana or English or both? Or should the teaching of science in English be introduced much earlier in the students' science education or much later?

The relationship between language and concept development has been explored in earlier studies (Ramorogo, 1992; Dow and Prophet, 1995). While these studies suggested that the language of expression did not seem to affect the incidental knowledge of genetic inheritance among students at junior secondary schools (Ramorogo, 1992; 1995), and that the language of instruction did not seem to affect the level of concept attainment of junior secondary school level (Dow and Prophet, 1995), the current study seems to suggest that students tend to handle their concepts with greater precision and depth in English when they feel proficient in the language. This may suggest that students tend to exhibit different worldviews in different contexts. That is, when conversing in English, the students may exhibit the Western worldview of biology and exhibit a traditional worldview when conversing in Setswana. This is what Ogunniyi (1997) posits as the 'contiguity hypothesis'. The contiguity hypothesis suggests that an individual exhibits only the dorminant worldview in a given context. If fully developed and found to be valid it might serve to elucidate the nature of collateral learning in science. Perhaps, the fact that students who converse in the Setswana seem to use English words where there are no Setswana equivalents, should serve as a starting point in this endeavour. In this sense, mixed language instruction could be one of the ways of trying to overcome the weaknesses of single language instruction.

Students who speak readily in English are likely to be those who went through a process of socialisation in English medium pre-schools and primary schools and as such should be children of parents who are educated and hold white collar jobs. While this is not the focus of this study, it could suggest a trend of "social reproduction" through which students from well to do homes are the ones who also have a language advantage in science classes.

Science is a micro-culture in that it has a characteristic language, thoughts and ways of doing things (Ogawa, 1986; 1987; Fensham, 1988; Ogunniyi, 1988; Ramorogo, 1992; Ramorogo and Wood-Robinson, 1994; Ogunniyi, et.al., 1995; Tobin, 1995; Jegede, 1996; Aikenhead, 1997; Cobern, 1997; Ramorogo and Kiboss, 1997). Students however, bring into the learning situation their own languages heavily tinted by their own linguistic histories (Thornton, 1974). It is this language that the student brings into the learning situation to construct his/her social world. As such, a student uses his/her language as a chief means to interpret and make sense of both everyday experiences and the learning of science. In a sense, learning science involves the acquisition of a new language as well as construction one's own scientific knowledge.

In other words, a good grasp of the language of science becomes a very important tool for conceptualisation and communication of what has been learned. Of course, fluency in English does not necessarily predispose one to a good grasp of the language of science. In fact, many students find the technical language of science quite inaccessible; a phenomenon that hampers rather than enhance student thinking in science. Perhaps, the tendency for science teachers to emphasise the "elite" language of science even at the expense of conceptual understanding (Prophet, 1989; 1990) is an attempt to address the need for competence in the language of science.

The foregoing argument depicts a dilemma for educational policy makers in that while Setswana might help to shape a learner's library of knowledge and to communicate reality in an effective and meaningful way, the currency or marketability of the language might prove to be a limiting factor. English also, while more consonant with the ideas and the language of science, appears to be limiting factor for students who have to learn it as well as the concepts of science at the same time.

4.8.6 Summary.

In this chapter, the results of the study were analysed and discussed. The results indicate that the interaction patterns of the exemplary and conventional teachers differ. Conventional teachers in this study seemed to give more verbal rewards, accept and challenge students' responses, lecture, rebuke, criticise and exert authority on the class more than their exemplary counterparts. Exemplary teachers, however, seem to supervise and give more individual attention to the students than the conventional teachers. Students in conventional classes seem to respond more to teacher questions as well as ask the teacher more questions than their exemplary counterparts.

The students in the co-operative and competitive treatment groups performed significantly better than the true control group. There is, there is however, no significant difference between the performance of the co-operative and competitive groups. Also, there is also no significant difference between the performance of the subjects in the individualistic group and those in the true control group.

The differences observed in the performance of low, average and high ability students at the pre-test stage seems to have disappeared at the post-test stage for the co-operative and competitive treatment groups. Also, the overall performance of the low ability students seems to have improved considerably compared to their high ability counterparts. The differences observed in the performance of different ability groups in the pre-test continue to persist in the post-test for students in the individualistic group. While in the true control group, the average ability students seem to have made significant cognitive gains.

The students believe that an exemplary teacher should: (i) provide opportunities for students to participate in the lesson; (ii) give homework related to what was taught and make sure that it is marked: (iii) encourage students to plan and carry out experiments and (iv) encourage students to discuss their work in small groups.

Students in the exemplary classes prefer group discussions and practical activities to teacher demonstrations, lectures and blackboard notes because practical activities and group discussions: (i) provide opportunities to share ideas; (ii) improve their self-concept; (iii) enhance their conceptual understanding. Students in the conventional classes prefer group discussions and practical activities because: (i) they help the students understand what the teacher taught better; and (ii) they provide a good chance for chatting.

CHAPTER FIVE

5.0.0 Conclusion and Implications.

5.0.1 Introduction.

This study explored the patterns of teaching biology in Botswana. Also determined are the relative effects of exemplary practice on the students' participation and achievement in biology lessons. In chapter one, the relevant questions and hypothesis were raised. Chapter two articulated the theoretical frame of reference for the study, while chapter three dealt with the methodology and methods employed in the study. Chapter four deals with the analysis and interpretation of the results. Chapter five provides a summary of the findings, examines the implications of the results, makes some recommendations and suggests areas warranting a closer scholarly attention.

5.1.0 Summary of findings.

The following is a summary of the findings of this study.

- Teachers in non-exemplary classes out talk their students while students in exemplary lessons out talk their teachers.
- Teachers' verbal and non-verbal interactions in non-exemplary lessons exceed those of their students while in exemplary lessons, the students verbal and non-verbal interactions exceed those of their teachers.
- The teachers' questions are mainly factual in both the exemplary and non-exemplary classes. Exemplary teachers, however, ask fewer rhetorical questions and more leading and probing questions than their non-exemplary counterparts.

- There is no significant difference between the achievement of boys and girls involved in this study with respect to the selected concepts in biology.
- Students in the co-operative and competitive experimental groups performed significantly better than those in the true control group in the Biology Achievement Test while there was no significant difference in the performance of the students in the individualistic experimental group and the true control group. There is also no significant difference in the performance of students in the true control and individualistic groups.
- While the pre-test and sex of the students do not seem to affect the performance of students, the use of exemplary instructional strategies and materials seem to have had an effect on the performance of students, particularly girls and weaker students. The fact that the variance observed in the performance of girls and boys in the pre-test of the control group persisted in the post-test while the variance in the experimental groups during the pre-test disappeared at the post-test stage seems to suggest the effectiveness of the exemplary instructional methods and learning materials in enhancing the performance of the students.
- Students perceive an exemplary teacher as the one who: (i) encourages student participation irrespective of their gender and academic ability, (ii) gives homework and marks it, (iii) encourages memorisation for tests and examinations, (iv) ensures that students are on-task, and allows no chorus answers.
- In exemplary classes: (i) the students are made aware of the objectives of the lesson; (ii) the teacher makes sure they all see the displays and the demonstration well; (iii) the students are encouraged to talk and get a good chance to talk; (iv) the

students discuss their results with the class and explain their findings and (v) discuss their observations and agree on what to record.

- Students in the exemplary lessons describe their experiences in terms of: (i) practical activities being enjoyable and providing opportunities to learn new things; (ii) being provided with specific episodes and useful skills, discussions and ideas; and (iii) being aided to understand the lesson.

- Students in non-exemplary lessons describe their experiences in terms of practical activities: (i) being useful in the future; (ii) confirming what was taught in theoretical lessons; (iii) being difficult, scary and dominated by boys, and (iv) being an opportunity for off-task behaviour.

- The reasons for the students in the exemplary lessons for preferring group discussions and practical activities to demonstrations, lectures and blackboard notes are that the former give them opportunities to share ideas and opinions and to improve their self-esteem.

- Students in non-exemplary lessons on the other hand consider such activities as helping them to understand what the teacher has taught as well as provide a chance for off-task behaviour.

- Practical work in biology lessons is characterised by experiments that require students to: (i) make accurate observations and measurements; (ii) use scientific apparatus correctly; (iii) use practical activities to confirm and verify facts and principles and (iv) illustrate theoretical concepts.

- The teachers involved in the study do not view: (i) their competence to organise practical work for their students; (ii) the number of periods allotted biology; (iii) their teaching loads and (iv) the availability of funds to purchase laboratory supplies and equipment as impediments to practical work in biology.

- The most common process skills which the teachers strive to develop in the students are: (i) observation and measurement; (ii) using scientific equipment correctly (ii) developing safe working habits and (iv) responding appropriately during accidents.
- Students in the exemplary classes would like classroom environments characterised by satisfaction and cohesion.
- Students in small group discourse tend to ask more procedural questions when the learning task is unfamiliar and more thought-provoking questions if the learning task is familiar or is not too difficult for them.
- Students use a variety of strategies to improve the chances that the group accepts their ideas. These include among others, discrediting the source, sarcasm, substantiating their arguments, lobbying for support and introducing new evidence.
- Students who spontaneously choose to discuss their ideas in the English language appear to discuss their ideas in more depth than those who spontaneously choose to speak in Setswana. However, the latter tend to bring into the discussions a lot of their everyday experiences.
- Fast learners tend to explore a considerable number of alternatives when solving a problem while slow learners seem to be satisfied with brief responses.

5.2.0 Conclusions.

The conclusions that can be drawn from this study include among others the following:

1. Teachers in non-exemplary classes spend more time talking than their students. In exemplary classes however, the students spend more time talking than their teachers. The tendency for teachers to dominate verbal interactions in classrooms has been reported earlier (e.g. Prophet and Rowell, 1990; Fuller and Snyder, 1991; Rammiki, 1991; Ogunniyi and Ramorogo, 1994). Perhaps, the reasons for this could be related to the teachers' perceptions of teaching and learning. If teachers perceive teaching in terms of transmission of knowledge, it would not be surprising that they spend a lot of time talking.

2. The induction workshop seems to have had some salutary effects on the interaction behaviours of exemplary teachers in the sense that their verbal interactions are substantially less than those of the non-exemplary teachers. Also, the verbal interactions of exemplary teachers are less than those of their students.

3. Despite the induction workshop, the teachers continue to ask a lot of factual questions. There seems to be no difference in the amount of factual questions asked by the exemplary and non-exemplary teachers during biology lessons. The tendency for teachers to use factual questions seems to be a common occurrence in science classrooms (e.g. Gall, 1970; Wragg, 1973; Onocha and Okpala, 1990; Ogunniyi, 1984; Ogunniyi and Ramorogo, 1994). This may not be unrelated to the predominantly factual nature of the questions in the national examinations. Exemplary teachers however, tend to ask more leading and probing questions and less rhetorical questions in line with the objectives of the training workshop.

4. The students rate as exemplary, teachers who are good managers of classroom activities, in terms of encouraging them and creating ample opportunities for them to participate in the learning activities, giving homework and marking it, ensuring that all are on-task and not allowing chorus answers. Good management seems to be a commonly envisaged trait of exemplary teaching. For instance, Garnett and Tobin (1988) described exemplary teachers as effective managers in terms of monitoring essentially three things; viz, disruptive behaviour, whether or not students are on-task, and understanding the subject matter in question.

5. The students also believe that exemplary teachers should encourage memorisation for tests and examinations. While an opinion like this one is contrary to the constructivist perspective of learning as envisaged in this study, it has shed light on an important aspect of learning. Perhaps, it indicates that students are comfortable with their teachers' modes of instruction because they seem to be working in the context within which learning has to take place. Thus, if the cherished objective is for the students to obtain good grades in the examinations and tests regardless of whether or not there is any evidence of conceptual understanding, then any method of teaching and learning that ensures that students get good grades including memorisation, is likely to be taken to represent a good example of learning and teaching in that given context.

6. Students' perceptions of their experiences in practical activities in exemplary and non-exemplary lessons are different. Practical activities in exemplary lessons were supposedly enjoyable, provided opportunities for the students to learn new things, provided episodes, useful skills, discussions and ideas and promoted understanding of

concepts while practical activities in non-exemplary lessons, were perceived as confirming theory, difficult, scary and dominated by boys.

7. Practical work in biology lessons in Botswana is done for didactic reasons. For this reason, practical work done in order for students to make accurate observations and measurements, use scientific apparatus correctly, confirm and verify facts and principles as well as illustrate theoretical concepts is common place in normal biology lessons. This may not be unrelated to the fact that the process skills that the teachers are helping students to develop do not go beyond making measurements and observations, using scientific equipment safely and developing safe working habits in the laboratory.

8. While students in the exemplary classroom environments perceived some difficulty with respect to engaging in classroom activities meant to engender construction of knowledge, they also had a measure of satisfaction when they successfully completed the learning tasks. The same students, however, would prefer classroom environments characterised by satisfaction and cohesion. The question that is raised here, is whether or not changing the classroom environment from that characterised by difficulty and satisfaction to that characterised by cohesion and satisfaction would increase the students' participation and achievement in biology lessons. Perhaps, this is one area that deserves further scholarly attention.

9. The nature of students' questions in small groups differs depending on the familiarity and or difficulty of the task at hand. The more familiar the task the more insightful questions the students appear to ask and the more difficult the task the more procedural questions the students seem to ask. An earlier study by Carlsen (1993)

suggested that students' rate of asking questions depends on activity and that the highest rate of questioning occurs in practical activities. Carlsen's study however, does not seem to have given as clear a picture of how the rate of questioning relates to the nature of the practical activities in terms of difficulty level and or familiarity as the present study has done.

10. The students' participation and achievement in exemplary biology lessons does not seem to vary with the students' sex. Perhaps, within the limits of the social learning model, both the boys and the girls have appreciable exposure to technology and the role models in the sense that, even at the time when the girls are socialised to carry out house hold chores, such chores expose them to a considerable amount of technological innovations. For instance, it is common place to find food processors, vacuum cleaners, electric kettles, electric irons, can openers, microwaves and other such items around the homes from which the children come. More mothers now tend to be role models to their children in terms of their level of education and careers. Apart from the mothers, the number of women in what used to be men only domains in the job market is constantly increasing. There are now women pilots, architects, drivers, managers, technicians, doctors and so on in Botswana.

11. The language that the students use to communicate their ideas seems to affect their rate of concept formation. The tendency for students to switch from English to Setswana is not uncommon. Students who without coercion choose to discuss their ideas in English, appear to discuss their ideas and concepts to a greater depth than their counterparts who spontaneously discuss their ideas in Setswana. Perhaps, as pointed out earlier, this corroborates a suggestion by Moje (1995) that language to a

some extent is a matter of choice and can be used as a form of identification. Teachers represent a 'particular academic speech community' and students who strive to be successful in the class will likely identify with the teacher by adopting the teachers' language patterns and those who for some reason do not seek to participate actively in the dominant classroom eco-culture would reject that language pattern and as such become alienated from the classroom community. Students who discussed their ideas in Setswana, tend to bring a lot of their everyday life experiences into the discussion. Using such experiences in the teaching process could prove to be a useful stepping stone in the construction of personal knowledge.

12. It has been observed that students in the individualistic experimental group did not perform better than the control group even though they were exposed to the same practical activities as those in the co-operative and competitive experimental groups. It seems that working as individuals did not engender the social interactions that encouraged negotiation of meanings and ideas as did, working in small group settings. It seems evident that experience alone is not enough; students need to make sense of these experiences in order for deeper conceptual understanding to occur. The social aspect of sense making embraces among other things, the need to provide learners with ample opportunities to compare their ideas with those of their peers and the scientific community and as such thrive to resolve the disparities that exist between their own conceptions of phenomena and the new information. While at a personal construction of knowledge level, making sense of experiences would espouse relating new information to what the learner already knows, it appears that social mediation in terms of interactions with the teacher and other students is an important and necessary

dimension of knowledge construction. Thus, a well planned classroom atmosphere in which student discourse in small groups becomes an integral part of practical activities may go a long way in creating opportunities for the students to construct their own knowledge in biology lessons.

5.3.0 Implications.

This study is important in the sense that it is probably the first of its kind in biology education in Botswana to provide a frame of reference in exemplary teaching. It systematically explored the relative effects of co-operative, competitive and individualistic teaching strategies in the context of an exemplary learning environment in which students do not only experience phenomena, but also are encouraged to make sense of their experiences amidst student-talk dominated classrooms.

Unlike the exemplary classrooms, conventional biology classrooms are characterised by lots of insipid teacher talk and fewer occasions of student talk. Considering that students in exemplary lessons out-performed those who were in conventional lessons, the usefulness of excessive teacher talk in learning situations becomes questionable. The important implication from this finding is how best to articulate both the teachers' and students' interactions in such a way that would enhance conceptual understanding amongst the students. Thus, it is not enough to encourage teachers to talk less in their lessons without putting concomitant strategies in place to ensure that students do not only have more time to talk in their lessons, but also use such talk meaningfully to construct their own knowledge.

Students involved in the study appear to believe that working together in small groups in a non-threatening environment enhanced their understanding of concepts better than would have been the case if they had been working independently. This raises the need for exemplary teaching to recognise the value of students' own ideas about teaching and learning and where appropriate take such ideas aboard during the process of teaching. It is clear that exemplary practice is built upon a common understanding of what constitutes worthwhile practices in the learning situation. If the teacher and the learners hold competing ideas about what constitutes exemplary practices in the learning environment, then they are at different worlds and as such the learning situation will continue to involve interactions between two social groups whose perceptions, ideas, beliefs, metaphors and overall worldviews are continuously incompatible. Since students already believe that they are learning more in exemplary learning settings, it would appear that the exemplary teachers were probably more successful than their non-exemplary counterparts because they used teaching strategies that their students believed constituted good teaching.

Student's perceptions about their experiences in practical activities have important implications for teaching and learning. The way biology is presented to the students is likely to influence the way they perceive it. For instance, if it is presented as a body of certain knowledge, then learning biology will be a matter of acquiring such a body of knowledge and the means of acquiring it would be characterised mainly by rote learning. In that case, practical work would be perceived in terms of helping the learner to acquire this body of knowledge. As a result, practical work would be devoid of cognitive challenges and the students themselves would not be motivated to explore alternative conceptions of the problem because there is only one correct answer to the problem after all. Hence, instead of exploring the problem, students tend to wonder as to what the correct response would be: a situation which encourages rote learning. When this happens, students are no longer making sense of their experiences and as such are not constructing any worthwhile knowledge of the phenomenon in question. If learning is perceived as a personal and social construction of knowledge, then, biology should be presented to the learners in such a way that they would realise that science is tentative and is a consensus of the scientific community. This involves presenting the content in such a way that the students would realise that there could be more than one solution to a given problem or that there are more than one way to approach a task. As such, the students would realise that their solutions to the problems could be affected by their approach to the problem. In other words, the students would be challenged to critically reflect on the problem they have to solve, the methods they have to use and also to continuously monitor their progress as the experiment unfolds. In this way, the focus would shift from a compulsion to get a correct answer to a conviction to make the process of exploring the problem more valid and reliable.

The fact that the process skills that the teachers are striving to develop include low order objectives like making correct observations and measurements, using scientific equipment correctly and developing safe working habits belies the constructivist dimension of classroom learning in biology lessons. Otherwise, how would students learn to engage themselves with higher order thinking and problem-solving skills if practical activities predominantly offer them only motor skills?

It appears that exemplary practice resulted in salutary cognitive gains for the low ability learner in the co-operative and competitive groups. Questions warranting empirical confirmation include: (i) Would the same kind of cognitive gain accrue to the slow learners when a larger spectrum of topics are taught to the students using exemplary teaching and learning materials? (ii) Would the same effect be observed if a retention test was administered? (iii) What would be the long-term effects of using exemplary teaching and learning materials on high ability students?

While students who used English to discuss their ideas in small groups seemed to go into much more detail, their counterparts who used Setswana used more of their daily experiences in their discussions. The implications of these finding warranting further investigation are: (i) What influences the students' choice of discourse language in small group discussions? (ii) What are the effects of familiar and unfamiliar topics on the students' choice and use of language in small groups? (iii) What are the relative effects of a given language on the students' concept development? iv) What are the pedagogical implications of the students' choice and use of a given language in small group discussions? (v) What are the effects of using a students' preferred language on their participation and achievement in biology?

Other related questions include: (i) What are biology teachers' perceptions of the nature of biology as a science subject and what are the implications of these perceptions on their interaction behaviours in biology lessons? (ii) What are the effects of teachers' preferred teaching strategies on students' performance and achievement in biology? (iii) What are students' perceptions of the factors that influence their performance in biology? (iv) What are teachers' perceptions of the ideal biology student and how do such perceptions of affect their selection of teaching strategies? (v) How does group size and composition affect the students' participation and achievement in biology? (vi) What are the effects of students' preferred classroom environments on their participation and achievement in biology?

5.4.0 Recommendations.

On the basis of the findings of this study, the following recommendations are proposed.

a) Learning settings in biology should be organised into small groups in which students are given ample opportunities to: (i) participate in performing some part of the group practical activities; (ii) freely participate in group discussions and (iii) decide and reach consensus about their findings as a group and negotiate consensus as a whole class.

b) Small co-operative or competitive groups should include students of all ability groups and sexes as this engenders considerable cognitive gains particularly for girls and low ability students in a traditional culture like Botswana.

c) Teachers should ensure that the process skills that the learning experiences in biology lessons seek to promote, go beyond making accurate measurements and observations skills. Students should be given opportunities to: i) select the relevant methods to investigate the problem at hand, determine what data to collect and when to collect them; and ii) evaluate the methods of data collection and the validity of the data collected.

d) The examination questions should demand deeper conceptual understanding so that teachers espouse teaching strategies that encourage construction of knowledge in their lessons. Since the O-level examinations are now localised, it is reasonable to expect that the examination should be used to direct the processes of teaching and learning in line with the constructivist perspective espoused in the curriculum.

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APPENDICES.

APPENDIX A

GRAMS: PULA
LEPHONE: 350849
LEX 2655 BD

REPUBLIC OF BOTSWANA

OFFICE OF THE PRESIDENT
PRIVATE BAG 001
GABORONE

Tel: 350808

REF: OP 46/1 LII (31) PAO II

March 5, 1996.

Mr. Gaobolelelwe Jimmy Ramorogo
Department of Maths and Science Education
University of Botswana
Private Bag 0022
Gaborone

Dear Sir,

RE: APPLICATION A RESEARCH PERMIT

Your application for a research permit of February 15, 1996 refers.

I am pleased to inform you that you have been granted permission to carry out research on Effects of Exemplary Teaching Materials on Students Performance in Biology. The study will be conducted at Senior Secondary School in Botswana.

The permit is valid for a period not exceeding six (6) months effective March 1, 1996.

The permit is granted subject to the following conditions:

1. Copies of any papers written as a result of the study shall be directly deposited with the Office of the President, Ministry of Education, National Archives, National Institute for Research and National Library Services.

2. You work in close liaison with the Ministry of Education.

Yours Faithfully,

J. Mosweu
for/PERMANENT SECRETARY TO THE PRESIDENT

cc. District Commissioner, Gaborone, Selebi-Phikwe, Francistown, Ghanzi, Kanye, Serowe, Mahalapye, Lobatse, Maun, Mochudi, Molepolole, Ramotswa.
Government Archivist
Director, National Library Services
Director, National Institute for Research
Permanent Secretary, Ministry of Education

JM/GT

EL: 371619

AX: 307097

ef

Republic of Botswana

DEPT OF SECONDARY EDUCATION
Ministry of Education
Private Bag 00297
Gaborone
Botswana

SE 11/17 II (2)

10 April 1996

TO WHOM IT MAY CONCERN

Mr Gaobolelelwe Jimm Ramorogo

Mr Ramorogo has been granted permission to carry research on the effects of Exemplary Teaching Materials on Students Performance in Biology at senior secondary schools in Botswana.

I will be grateful if you could kindly give him all the assistance he will need.

Yours faithfully

G Makunga
for/DIRECTOR SECONDARY EDUCATION

UNIVERSITY OF BOTSWANA
Centre for Graduate Studies in Education
National Institute of Research

Private Bag 0022 Gaborone Botswana
Telephone (267) 351151 x 2397 Fax (267) 356591 Telex 2429 BD

14 June 1996

Reference: Account SAREC III P355

To Mr Mathew
Bursar's Office

Subject: **Mr. G.J. Ramorogo, DMSE—PhD student University of Western Cape.**
"Effects of Exemplary Teaching and Learning Materials on the Performance of Students in Biology"

Mr. Gaobolelelwe J. Ramorogo is seeking additional funds to complete field work for his PhD at the University of the Western Cape. We have considered his research proposal and budget and feel that his request is justified.

We therefore approve a supplementary amount of P8000.00 (Eight Thousand Pula) from the SAREC account to be disbursed to support his research study. Please offer Mr. Ramorogo every assistance with details regarding the administration of this amount.

Sincerely,

17/6/96

Ansu Datta, Director,
National Institute of Development Research and Documentation

Mbakiso Dambe
BERA Executive

Bob Prophet, Acting Director
Graduate Studies and Research
Faculty of Education

cc: G.J. Ramorogo
Dean, Education
HoD, DMSE

N.I.R.
14-6-96
AKD
Copy for inf. to:
O/G Reg. No.:
Passed for filing:

DIRECTOR
1996 -06- 14
FOR GRADUATE STUDIES
FACULTY OF EDUCATION

ANIMAL NUTRITION

Form Three

Lesson plans
(Cooperative)

1996

Dear Teacher

The exemplary materials are designed to help students to learn science in a meaningful way. In this sense, they require students to reflect on what they are doing. It is through this reflection that students are expected to evaluate their ideas and hence be engaged in the process of constructing new knowledge. Students, therefore, should be allowed to carry out the experiments, critique the procedure, suggest ways of testing the validity of their ideas, the data they collect and the methods used to collect such data.

Students' ideas and how they could be mobilized to enhance learning are central. The teacher's role in this process is to facilitate the process of knowledge construction by the pupils. A classroom environment in which students are free to ask questions, respond to questions without feeling threatened and make suggestions needs to be created to encourage the development of the pupils own ideas.

The teacher's guides are meant to show typical responses to the questions posed. They are not in anyway exhaustive. Student responses therefore, need to be very carefully considered with a view to develop them to scientifically accepted ideas. This can in part be achieved if the teacher is able to reflect on the content of the pupils' responses. Reflective practice therefore, should underpin all activities in exemplary classes.

It is necessary for you to reflect on the content and pedagogical strategies before the lesson, and in addition to these, reflect on the classroom interactions during and after the lesson.

The pupils' workbooks are their own property. They should be encouraged to write in them as well as use them effectively for learning.

Lesson Plan 1 - Feeding (Cooperative)

What	How	time	Materials
Introduction Nutrition	Divide pupils into groups of five (pupils should stick to these groups through out this study). Ask each group to choose a leader and a reporter. Explain nutrition as the relationship between organisms and their food i.e. How the organism obtains food, what it feeds on, how it feeds, the effects of food on its health, population and growth and how best it is suited to feed on that food. Ask pupils to do activity 1 in the workbook. Go around the class and discuss with each group. Allow for ingenuity and full expression of their views. Ask thought-provoking questions e.g. Why should organisms feed? etc.	5 5 15	
Different ways of feeding	allow pupils to spend 10 minutes on each of activities 2,3,4,5 and 6. Again go round the groups and encourage them to reflect on their ideas.	50	
Conclusion	Summarize the main points a) plants and animals need food. b) plants make their own food. c) animals depend on plants and on other animals for food. d) living things obtain food in different ways e) animals have developed structures that enable them to feed on their type of food.	5	

Lesson Plan 2 - Feeding continued (Cooperative)

What	How	Time	Materials
Introduction	Ask questions about the previous lesson. e.g. What did we learn about ways in which certain organisms feed or Thomo found a bird with a long thin beak. He thought it fed on meat. Would you agree with him? Why? Allow for discussion and exchange of views.	10	Chalkboard
The growth , reproduction and the health of organisms depend on the availability of food.	Open a debate to explore pupils' ideas about inter-dependence of organisms e.g. "Agricultural demonstrators have recently been going around advising farmers not to keep too many cattle on one piece of land" Do you agree or disagree with this idea? Divide the class into smaller groups of five pupils. Each group of five should then discuss its reasons. Groups are free to consult with each and help each other. Pick on pupils at random from the groups to present the views of their group. Note on the board the points pupils raise which would be used later to build the notion of inter-dependence of organisms. Cooperative groups to make observations and notes. Use these ideas to develop: i. relationship between food and population growth. ii. energy transfer along the pyramid of numbers.	3 10 7 5	Chalkboard.
Relationship between organisms their food.	Take pupils out to a piece of grassland on the school grounds (only five minutes walk). Define the perimeter in which the search will be done. It should be such that no one will be out of sight. Let each group follow its own path and do activity 1. (Snakes, spiders and scorpions if spotted, should be treated as lethal)	35 (5 min. for wal-king)	Workbooks, insect nets, hand lenses.

What	How	Time	Materials
Conclusion.	Use the question and answer to reflect on the i. the relationship between the amount of food and the number of organisms feeding on it. ii. the relative physical size of organisms that feed on others as compared to those that are fed on.	10	

Lesson Plan 3 - Classes of nutrients (Cooperative)

What	**How**	**Time**	**Materials**
Introduction	Link current lesson with the previous one. e.g. We learnt that living things need food. Give examples of some animals and the food they eat. Do animals need only one type of food? Give examples of animals that eat a variety of food. What do they eat?	10	Chalkboard
Classes of food.	Divide pupils into groups of five and ask them to list at least ten different types of food they eat. Why do they need different types of food? Let them respond to this question in their groups. The reporters should then report the responses of their groups on the chalkboard divided into seven columns. The points of all the groups should be intergrated for the benefit of all. Use the pupils' responses to develop the concept of classes of nutrients. e.g "some food types gives us energy" should be followed up with questions like - what are the examples of such types of food? Examples of fats and carbohydrates may be given by the pupils. Using these examples, introduce fats and carbohydrates as two groups of food that give us energy.	2 3 10 5 15	chalkboard

What	How	Time	Materials
Examples of food in the various food classes.	Pupils should be divided into six groups now. Each group should have a Manila paper and at least two old magazines. One group should cut out pictures of food representing carbohydrates and paste them on the Manila paper and label it. Under each picture should be the name of the food. Another group should paste examples of food representing proteins and so forth. Pin up the posters at the back of the class.	15 2	Manila paper Glue sticks, markers, pairs of scissors, old magazines, drawing pins or bostik.
	Arrange pupils such that all can see the display. Summarise the examples of different classes of nutrients.	3 10	
Summary	Discuss the main points of the lesson.	5	

Lesson Plan 4 - Food tests (Starch) (Cooperative)

What	How	Time	Materials
Introduction	Lecture - Explain that it is possible to test for the nutrients contained in food. Ask pupils to suggest a reagent that can be used to test for starch. Ask pupils to put a drop of iodine on a white tile and to describe the colour of iodine.	8	iodine solution. white tile
Identifying a test for starch	Each group should have $10cm^3$ of the following solutions: A= 1% albumen solution, B=10% glucose solution, C=1% starch solution, D=Cold water, E=Hot water on their tables. Pupils should not be told solutions A-E are.		1% albumen solution. 10% glucose solution, 1% starch solution. iodine solution. droppers. test-tubes
	Divide the pupils into their groups. Ask pupils to Divide tasks among themselves and start work immediately. Pupils should perform their tasks simultaneously to save time. They should record the colours as they perceive them . Do not tell them the colours. They should then respond to the questions that follow.	5 5 5	
	Draw a table with seven columns on the chalkboard for the pupils to report their findings.	10	Chalkbo-ard
	Lead a discussion to help pupils compare and resolve disparities between their results. You should ask questions like " Do we all get the same results? Which results are not the same as others? Are they wrong results? Why?	7	

What	How	Time	Materials
conditions under which iodine reacts with starch	Ask pupils to divide the tasks among themselves and carry out activity 2. They should do their activities simultaneously to save time. Ask them to discuss and respond to the questions that follow activity 2.	8 5	1% starch solution, Bunsen/ spirit burner
Testing for the presence of starch.	Devide the tasks amongst groups of pupils. Add water to food samples which are already in powder form. Groups should test these while you are preparing the remaining food samples. Reward groups for cooperating together to complete activities and for sharing responsibilities e.g. through verbal reinforcement.	20	Potato, bread, maize meal, banana, apple, dried milk, sorghum meal, phane.
Conclusion	Wrap up the main points of the lesson in a question and answer session. Collect workbooks for marking.	7	

Lesson Plan 5 - Food tests (Glucose) (Cooperative)

What	How	Time	Materials
Introduction	Review the previous lesson. Ask pupils to look at the poster for carbohydrates produced in the other lesson. Ask them which ones of those are sweet. These are sugars. Ask them to give examples of the sugars they know. Which sugar do they use during athletic sports? Tell pupils that it is possible to test for the presence of glucose. Ask them to suggest a reagent that could be used to do this. Introduce Benedict's solution and ask the pupils to describe its colour.	10	Benedict's solution
Benedict's solution changes colour when glucose is present.	Ask the pupils to go into their groups and the group leaders to collect solutions A - E and all the necessary materials for their groups. Pupils should then divide the work among themselves and start working in their groups. They should then respond to the questions that follow. Draw a table with seven columns on the board on which the pupils will report their findings. Ask the recorders to fill in their in the table on the chalkboard. Lead a class discussion of the results.	5 10 5 5 5	
Testing food samples for the presence of glucose.	Add water to the food samples that are already in powder form. Crush those that are not in powder form in a mortar with a bit of water. Assign each group particular foodstuffs to test. Draw the table on the board and ask the pupils to fill in their results as soon as they finish. Discuss the results with the pupils in a whole class discussion. Pupils should now copy the results from the board.	15 3 10 7	
Summary	Summarise the main points of the lesson.	5	

Lesson Plan 6 - Food tests (Proteins) (Cooperative)

What	How	Time	Materials
Introduction	Review test for glucose. Ask for the examples of food containing glucose. Introduce the pupils to the reagents used in the Biuret test. Explain the precautions to be taken when handling sodium hydroxide.	10	Copper sulphate. sodium hydroxide.
Identifying a test for proteins.	Ask two pupils from each group to collect the materials needed for each group. Divide tasks in activity one among cooperative groups. The groups should predict possible colour changes they would expect when the named food stuffs in their worksheet are tested using the Biuret test. Lead a class discussion and let the pupils explain the reasons for their prediction.	5 15 5 10	NaOH, $CuSO_4$, A=1% albumen. B=10% glucose. C=1% starch. D= cold water E= hot water. Test-tube racks and holders.
Testing food for proteins.	Assign each group particular foodstuffs to test. Liquid foods samples can be tested directly. Solid foodstuffs should be crushed in a bit of water	15	NaOH. $CuSO_4$. fish. lean meat. mealie-meal. milk. mophane caterpillar. sorghum meal. cooking oil. test-tubes. test-tube holders and racks.
Summary	Discuss the results in a whole class discussion. Give notes.	10 10	

Lesson Plan 7 - Food tests (Fats) (Cooperative)

What	How	Time	Materials
Introduction	Divide pupils into groups of five and ask them to suggest how they could test for fats. The groups should choose a leader and a reporter before starting. Ask the reporters to quickly describe their groups' responses. Look out in the pupils responses for elements of the greasy spot test and the emulsion test. Note points that could be used to develop the idea of greasy spot test and the emulsion test. Demonstrate the greasy spot test.	10 15	Cooking fat, filter paper.
Identifying a test for fats - the emulsion test.	Pupils should collect materials and do activity 1 and respond to the questions that follow. Use the question and answer method to summarise this.	20	Cooking oil, alcohol, test-tubes.
Testing food samples for fats.	Assign tasks to the groups and let them continue with activity 2. Draw a table on the chalkboard and get the reporters to fill their group results into it. Discuss the results with the class through a question and answer method.	25	alcohol, mortar, pestle, test-tubes, filter funnel, filter paper, retort stand, boss heads and clamp, ground nuts, cheese, potato, meat, mophane caterpillar.
Conclusion	Review the two tests for fats. Ask pupils to give example of food rich in fats.	10	

Lesson Plan 8 - Dentition (Cooperative)

What	How	Time	Materials
Introduction	Explain that animals in most cases get their food as materials that cannot readily be used by the body. Such materials need to be broken down to smaller units that can be conveniently absorbed by the body. Ask pupils in their groups to give examples of food which may need to be broken down to smaller pieces when we eat and to describe how such food is broken down in the mouth. Summarise the groups' responses and emphasise the role of teeth in mechanical digestion.	2 5 3	
Importance of the teeth.	Pupils should in their groups discuss the importance of teeth. Summarise this by allowing each group to give one of its responses. Responses may include i. teeth adorn us. ii. they maintain the shape of the mouth. iii. can be used for fighting and scaring away enemies. chewing etc.	5 5	
Identifying different types of teeth.	Pupils should work in pairs within their groups to do activity 1.i). After this they should get back into their groups and continue with the rest of activity. Discuss the responses with the pupils in their groups. Limit your role to reflecting discrepancies in their responses and let them deal with that.	5 30	
Relating dentition to diet.	Pupils should do activity 2 and respond to the questions.	10	Skulls from goats and sheep.
Summary	Summarise the lesson and let the pupils prepare for Activity 1. lesson 10.	10	
Notes	Give brief notes.	5	

Lesson Plan 9 - Dental formulae (Cooperative)

What	How	Time	Materials
Introduction	Review last lesson. Ask pupils the number and to describe the shapes of the different types of teeth in an adult with a full set. Get pupils into groups of five and in their groups to think of a way briefly and clearly represent the number and types of their teeth to a friend. Divide the board into the number of groups and have the reporters fill in their formulae. Develop the ideas of the pupils to develop the concept of dental formula. e.g. some pupils could have used letters like C, I.P, and M in their formulae.	3 7 5 10	Chalkboard
Dental formula	Let the pupils in their groups do activity one and answer the questions in the process.	20	
Dental formula is related to the diet of the organism.	Let the pupils in their groups do activity 2 and answer the questions. Pick some pupils from the groups to present their responses on the board. Allow for comments and questions.	15 10	
Summary	In summary review the steps involved in deriving a dental formula.	10	

Lesson Plan 10 - Tooth Structure (Cooperative)

What	**How**	**Time**	Materials
introduction	Explain the concept of milk and permanent teeth. Use the pupils existing ideas in this process.	10	Teeth from the test-tubes prepared in the last lesson.
	Ask the cooperative groups to take out the experiments set up in the last lesson and continue in their groups of five with activity 1.	20	
	Get a pupil from each group to describe the hardness of a tooth in the hydrochloric acid as opposed to those in water and saliva. Use this observation to explain the concept of tooth decay.	5	
Care for teeth	Pupils should now still in their groups discuss activity 2. Allow for ingenuity and experiences in this discussion.	15	
	Lead a whole class discussion of activity 2. Let the pupils freely discuss plausible methods they have suggested and consider the advantages and disadvantages of those.	20	
Summary	Review the structure of the tooth and care of teeth.	10	

Lesson Plan 11 - The Alimentary Canal (Cooperative)

What	How	Time	Materials
Introduction	Ask pupils to go into groups of five and describe the path followed by food from the time it is swallowed to the time it leaves the body through the anus.	10	
The alimentary canal - rat.	Arrange pupils around the dissected rat so that all can see. Pick on some pupils at random and ask them to identify parts of the alimentary canal that they recognise. Ask one pupil to count the incisors on the upper and lower jaws, another to count canines etc. Write these on the board. Get pupils to locate the trachea and the oesophagus. Then to suggest their functions.	20	Dissected rat, chalkboard
	Ask pupils to get into their groups and respond to Activity one questions 2a-c.	15	
Small and large intestines, caecum, rectum and anus.	With pupils around the demonstration table, ask them to identify the small intestines, large intestine, caecum, rectum and the anus.	5	
	Ask pupils to identify the liver and pancreas. On the liver, pupils should locate the gall bladder. Cut the gall bladder and get a pupil to describe the colour of bile. Explain the role of the liver in the digestion of fats.	10	
	Get each group to respond to the remaining part of activity 1.	5	
The human alimentary canal.	In their groups, pupils should label the diagram of the human alimentary canal.	5	
Summary	Review the names of parts of the alimentary canal. Hand out notes.	10	

Lesson Plan 12 - Digestion (In the mouth) (Cooperative)

What	**How**	**Time**	Materials
Introduction	Ask pupils to get into groups of five, choose a leader and a reporter. Ask the to describe what happens to say a piece of bread in the mouth when we eat it.	5	Chalkboard
	Get any two reporters to each briefly describe what happens. Use those responses to develop an operational definition of digestion with the pupils. e.g. "the breaking down of large food molecules into smaller units that the body can absorb".	10	
Mechanical and chemical digestion.	Still in their groups, give each pupil a piece of bread to chew. (Hands should be thoroughly washed before handling food). Pupils should then proceed with activity 1.	10	Pieces of bread.
	In a whole class discussion, summarise activity 1. Establish the concept of Mechanical and chemical digestion. Use a knife to cut a piece of bread into smaller pieces to demonstrate Mechanical digestion. Relate the sweet taste they felt when they chewed a piece of bread to a chemical change in the bread, hence chemical digestion.	10	
Effect of saliva on starch.	Use 2% starch solution to represent solution X. Each group should have about 3ml of this . Ask pupils to carry out activity 2, record their results and respond to the questions.	25	25ml of 2% starch solution, 3 test-tubes per group, beakers, Bunsen burners, iodine, Benedict's solution and spotting trays.
	Engage the whole class in a discussion of the results.	10	
Summary	Review Mechanical and chemical digestion.	10	

lesson Plan 13 - Digestion (Stomach) (Cooperative)

What	How	Time	Materials
Introduction	Explain that enzymes are proteins and as such are affected by heat and pH or acidity and alkalinity. Use universal indicator or litmus paper check the pH of saliva. Get pupils to infer the pH at which ptyalin would digest starch. Ask pupils what could happen if the pH is either too alkaline or too acidic. Get pupils to discuss this in their groups and compare their response with the result of activity 1.	7 5	Universal indicator paper or litmus paper.
Factors affecting the activity of ptyalin.	Divide tasks among the groups and let pupils do activity 1. Move around to ensure that pupils are on-task. Probe pupils to interpret and explain the results they are getting.	35	rubber bands, test-tubes, starch solution. beakers. tripod stands. gauze. Bunsen burners. iodine solution. Benedict's solution.
Digestion in the stomach - video show	Let the pupils read the questions. Play the video for pupils to watch. They should take notes. Pupils should then respond to the questions in their groups of five. Provision should be made for the pupils to see the video again say during afternoon studies if they so wish.	3 10 10	A ten minutes long video discussing digestion.
Conclusion.	Review i. the pH in the stomach. ii. the effect of the pH on the activity of ptyalin. iii. pepsin as the enzyme active in the stomach iv. peristalsis.	5	

Lesson Plan 15 - Absorption (Cooperative)

What	How	Time	Materials
Introduction	Review digestion of carbohydrates, proteins and fats. Pupils should in their groups of five state where these are digested and state the end products of such digestion. Explain that at the tend of digestion all the glucose, amino-acids, fatty-acids and glycerol are all in the ileum and need to be taken out of it to the cells where they are needed. This is achieved through absorption.	10	
absorption through a semi-permeable membrane.	Divide pupils into groups and let each group perform the experiment. Draw a table on the chalkboard into which groups will fill in their results. Ask reporters to fill in their responses on the board. Discuss the results. Help pupils to reflect on their procedure if the results are not what they expect.	30 5 10	dialysis membrane, glass rods, starch solution, rubber bands, beakers, iodine solution, Benedicts' solution, Bunsen burners, tripods and gauze.
Structure of the small intestine	Divide the pupils into groups of three and ask one member of the group to collect a bio-viewer and bio-strip. Demonstrate how to use a bio-viewer and ask the pupils to do Activity 2. Groups are free to consult with each other. Discuss activity 2 in a whole class discussion session.	5 15 5	Bio-viewers Bio-strip M17.
Conclusion	Review the process of absorption and how the small intestine is adapted for absorption.	5	

ANIMAL NUTRITION

Form Three

Lesson plans
(Individualistic)

1996

Dear Teacher

The exemplary materials are designed to help students to learn science in a meaningful way. In this sense, they require students to reflect on what they are doing. It is through this reflection that students are expected to evaluate their ideas and hence be engaged in the process of constructing new knowledge. Students, therefore, should be allowed to carry out the experiments, critique the procedure, suggest ways of testing the validity of their ideas, the data they collect and the methods used to collect such data.

Students' ideas and how they could be mobilized to enhance learning are central. The teacher's role in this process is to facilitate the process of knowledge construction by the pupils. A classroom environment in which students are free to ask questions, respond to questions without feeling threatened and make suggestions needs to be created to encourage the development of the pupils own ideas.

The teacher's guides are meant to show typical responses to the questions posed. They are not in anyway exhaustive. Student responses therefore, need to be very carefully considered with a view to develop them to scientifically accepted ideas. This can in part be achieved if the teacher is able to reflect on the content of the pupils' responses. Reflective practice therefore, should underpin all activities in exemplary classes.

It is necessary for you to reflect on the content and pedagogical strategies before the lesson, and in addition to these, reflect on the classroom interactions during and after the lesson.

The pupils' workbooks are their own property. They should be encouraged to write in them as well as use them effectively for learning.

Lesson Plan 1 - Feeding (Individualistic)

What	How	time	Materials
Introduction Nutrtion	Explain nutrition as the relationship between organisms and their food i.e. How the organism obtains food, what it feeds on, how it feeds, the effects of food on its health, population and growth and how best it is suited to feed on that food. Ask pupils to do activity 1 in the workbook. Go around the class and discuss with pupils who need your help. Allow for ingenuity and full expression of their views. Ask thought-provoking questions e.g. Why should organisms feed? etc.	5 15	
Different ways of feeding	allow pupils to spend 10 minutes on each of activities 2,3,4,5 and 6. Again go round and encourage them to reflect on their ideas.	50	
Conclusion	Summarize the main points a) plants and animals need food. b) plants make their own food. c) animals depend on plants and on other animals for food. d) living things obtain food in different ways e) animals have developed structures that enable them to feed on their type of food.	10	

Lesson Plan 2 - Feeding continued (Individualistic)

What	How	Time	Materials
Introduction	Ask questions about the previous lesson. e.g. What did we learn about ways in which certain organisms feed or Thomo found a bird with a long thin beak. He thought it fed on meat. Would you agree with him? Why? Allow for discussion and exchange of views.	10	Chalkboard
The growth , reproduction and the health of organisms depend on the availability of food.	Open a debate to explore pupils' ideas about inter dependence of organisms e.g. "Agricultural demonstrators have recently been going around advising farmers not to keep too many cattle on one piece of land" Do you agree or disagree with this idea?		Chalkboard.
	Let individual pupils make contributions by first writing down their ideas and later picking on a few who are ready to report. Note on the board all the points pupils raise which would be used later to build the notion of inter dependence of organisms. Students should make individual observations and notes.	15	
	Use these ideas to develop: i. relationship between food and population growth. ii. energy transfer along the puramid of numbers.	10	
Relationship between organisms their food.	Take pupils out to a piece of grassland on the school grounds (only five minutes walk). Define the perimeter in which the search will be done. It should be such that no one will be out of sight. Let each one follow his/her path and do activity 1. (Snakes, spiders and scorpions if spotted, should be treated as lethal)	35 (5 min. for wal-king)	Workbooks. insect nets. hand lenses.
Conclusion.	Use the question and answer to reflect on the i. the relationship between the amount of food and the number of organisms feeding on it. ii. the relative physical size of organisms that feed on others as compared to those that are fed on.	10	

Lesson Plan 3 - Classes of nutrients (Individualistic)

What	How	Time	Materials
Introduction	Link current lesson with the previous one. e.g. We learnt that living things need food. Give examples of some animals and the food they eat. Do animals need only one type of food? Give examples of animals that eat a variety of food. What do they eat?	10	Chalkboard
Classes of food.	Ask pupils to list at least ten different types of food they eat. Why do they need different types of food? Pick on several pupils to report their responses. Summarise these on the Chalkboard. Use the pupils' responses to develop the concept of classes of nutrients. e.g "some types of food gives us energy" should be followed up with questions like - what are the examples of such types of food? Examples of fats and carbohydrates may be given by the pupils. Using these examples, introduce fats and carbohydrates as two groups of food that give us energy.	10 10 15	Chalkboard
Examples of food in the various food classes.	Pupils should be assigned one of the six groups of food. Each pupil should have a piece($^{1}/_{6}$) of Manila paper and an old magazine. One group working individually should cut out pictures of food representing carbohydrates and paste them on the Manila paper and label it. Under each picture should be the name of the food. Another group should paste examples of food representing proteins and so forth. Pin up the posters at the back of the class.	15 2	Manila paper Glue sticks, markers, pairs of scissors, old magazines, drawing pins or bostik.

What	How	Time	Materials
	Arrange pupils such that all can see the display. Summarise the examples of different classes of nutrients.	3 10	
Summary	Discuss the main points of the lesson.	5	

Lesson Plan 4 - Food tests (Starch) (Individualistic)

What	How	Time	Materials
Introduction	Lecture - Explain that it is possible to test for the nutrients contained in food. Ask pupils to suggest a reagent that can be used to test for starch. Ask pupils to put a drop of iodine on a white tile and to describe the colour of iodine.	8	iodine solution, white tile
Identifying a test for starch	Each pupil should have 2cm^3 of one of the following solutions: A= 1% albumen solution. B=10% glucose solution. C=1% starch solution. D=Cold water. E=Hot water on their tables. Pupils should not be told solutions A-E are.	5	1% albumen solution. 10% glucose solution. 1% starch solution. iodine solution. droppers. test-tubes
	Pupils should perform their tasks simultaneously to save time. They should record the colours as they perceive them . Do not tell them the colours. They should then respond to the questions that follow.	5	
	Draw a table on the chalkboard into which the pupils will should report their findings. Ask five pupils to fill in their results into the table on the board. Each for one of the solutions tested	5	Chalkbo-ard
	Lead a discussion to help pupils compare and resolve disparities between their results. You should ask questions like " Do we all get the same results? Which results are not the same as others? Are they wrong results? Why?	10 7	

What	How	Time	Materials
conditions under which iodine reacts with starch	Divide the tasks among the pupils and let them carry out activity 2. They should do their activities simultaneously to save time. Ask them to respond to the questions that follow activity 2.	8 5	1% starch solution, Bunsen/ spirit burner
Testing for the presence of starch.	Divide the tasks among the pupils. Add water to food samples which are already in powder form. Individual pupils should test these while you are preparing the remaining food samples. Praise individual performance.	20	Potato, bread, maize meal, banana, apple, dried milk, sorghum meal, phane.
Conclusion	Wrap up the main points of the lesson in a question and answer session. Collect workbooks for marking.	7	

Lesson Plan 5 - Food tests (Glucose) (Individualistic)

What	How	Time	Materials
Introduction	Review the previous lesson. Ask each pupil to look at the poster for carbohydrates produced in the other lesson. Ask individual pupils which ones of these foodstuffs are sweet. These are sugars. Ask them to give examples of the sugars they know. Which sugar do they use during athletic sports? Tell pupils that it is possible to test for the prescence of glucose. Ask individual pupils to suggest a reagent that could be used to do this. Introduce Benedict's solution and ask individual pupils to describe its colour.	10	Benedict's solution
Benedict's solution changes colour when glucose is present.	Divide the tasks among the pupils. Ask each pupil to collect appropriate solutions among solutions A - E together with all the necessary materials. Each pupil should then start working. Each pupil should then respond to the questions that follow. Draw a table the board on which the pupils will report their findings. Ask individual pupils to fill in their results in the table on the chalkboard for the solution they tested. Lead a class discussion of the results.	5 10 5 5 5	
Testing food samples for the presence of glucose.	Add water to the food samples that are already in powder form. Crush those that are not in powder form in a mortar with a bit of water. Assign each pupil particular foodstuffs to test. Draw the table on the board and ask the pupils to fill in their results as soon as they finish. Discuss the results with the pupils in a whole class discussion. Pupils should now copy the results from the board.	15 3 10 7	
Summary	Summarise the main points of the lesson.	5	

Lesson Plan 6 - Food tests (Proteins) (Individualistic)

What	How	Time	Materials
Introduction	Review test for glucose. Ask for the examples of food containing glucose. Introduce the pupils to the reagents used in the Biuret test. Explain the precautions to be taken when handling sodium hydroxide.	10	Copper sulphate, sodium hydroxide.
Identifying a test for proteins.	Ask individual pupils to collect the materials needed. Divide tasks among individual pupils and ask them to start doing activity one. Individal pupils should predict possible colour changes they would expect when the named food stuffs in the worksheet are tested using the Biuret test. Lead a class discussion and let the pupils explain the reasons for their prediction. Pick on pupils who would finish first and encourage pupils to compete for good answers.	5 15 5 10	NaOH, $CuSO_4$, A=1% albumen, B=10% glucose, C=1% starch, D= cold water E= hot water. Test-tube racks and holders.
Testing food for proteins.	Assign each pupil particular foodstuffs to test. Liquid food samples can be tested directly. Solid foodstuffs should be crushed in a bit of water.	15	NaOH, $CuSO_4$, fish, lean meat, mealie-meal, milk, mophane caterpillar, sorghum meal, cooking oil, test-tubes, test-tube holders and racks.
Summary	Discuss the results in a whole class discussion. Give notes.	10 10	

Lesson Plan 8 - Dentition (Individualistic)

What	How	Time	Materials
Introduction	Explain that animals in most cases get their food as materials that cannot readily be used by the body. Such food materials need to be broken down to smaller units that can be conveniently absorbed by the body. Ask pupils to give examples of food which may need to be broken down to smaller pieces when we eat and to describe how such food is broken down in the mouth. Summarise the responses and emphasise the role of teeth in mechanical digestion.	2 5 3	
Importance of teeth.	Pupils should in suggest the importance of the teeth. They should indicate their intention to respond by raising their hands. Summarise this by allowing pupils to say their responses. Responses may include i. teeth adorn us, ii. they maintain the shape of the mouth, iii. can be used for fighting and scaring away enemies, chewing etc.	5 5	
Identifying different types of teeth.	Pupils should use mirrors to do activity 1.i). After this they should continue with the rest of activity 1. Discuss the responses with the pupils. Limit your role to reflecting discrepancies in their responses and let them deal with that.	5 30	
Relating dentition to diet.	Pupils should do activity 2 and respond to the questions.	10	Skulls from goats and sheep.
Summary	Summarise the lesson and let the pupils prepare for Activity 1, lesson 10.	10	
Notes	Give brief notes.	5	

Lesson Plan 9 - Dental formulae (Individualistic)

What	How	Time	Materials
Introduction	Review last lesson. Ask pupils the number of the different types of teeth in an adult with a full set and to describe their shapes .	3	Chalkboard
	Get individual pupils to think of a way in which they can briefly and clearly represent the number and types of their teeth to a friend. They should use the back of their note books for this.	7	
	Ask pupils who have done it to present their findings on the board.	5	
	Develop the ideas of the pupils to develop the concept of dental formula. e.g. some pupils could have used letters like C, I, P, and M in their formulae.	10	
Dental formula	Let the pupils do activity one and answer the questions in the process.	20	
Dental formula is related to the diet of the organism.	Let the pupils do activity 2 and answer the questions.	15	
	Pick some pupils to come and present their responses on the board. Allow for comments and questions.	10	
Summary	In summary review the steps involved in deriving a dental formula.	10	

Lesson Plan 10 - Tooth Structure (Individualistic)

What	**How**	**Time**	Materials
introduction	Explain the concept of milk and permanent teeth. Use the pupils existing ideas in this process. Each pupil should have a tooth from each of the beakers set up in the last lesson and continue with activity 1. Get one student to describe the hardness of a tooth in the hydrochloric acid as opposed to those in water and saliva. Use this observation to explain the concept of tooth decay.	10 20 5	Teeth from the test-tubes prepared in the last lesson.
Care for teeth	Pupils should now do activity 2. Allow for ingenuity and experiences in this discussion. Lead a whole class discussion of activity 2. Let the pupils freely discuss plausible methods they have suggested and consider the advantages and disadvantages of those.	15 20	
Summary	Review the structure of the tooth and care of teeth.	10	

Lesson Plan 11 - The Alimentary Canal (Individualistic)

What	How	Time	Materials
Introduction	Ask pupils to describe the path followed by food from the time it is swallowed to the time it leaves the body through the anus at the back of their note books. Use their responses to define the alimentary canal as a continuous muscular tube running from the mouth to the anus.	10	
The alimentary canal - rat.	Arrange pupils around the dissected rat so that all can see. Pick on some pupils at random and ask them to identify parts of the alimentary canal that they recognise. Ask one pupil to count the incisors on the upper and lower jaws, another to count canines etc. Write these on the board. Get pupils to locate the trachea and the oesophagus. Then to suggest their functions.	20	Dissected rat. chalkboard
	Ask each pupil to respond to Activity one questions 2a-c.	15	
Small and large intestines. caecum. rectum and anus.	With pupils around the demonstration table. ask them to identify the small intestines. large intestine. caecum. rectum and the anus.	5	
	Ask pupils to identify the liver and pancreas. On the liver. pupils should locate the gall bladder. Cut the gall bladder and get a student to describe the colour of bile. Explain the role of the liver in the digestion of fats.	10	
	Get each pupil to respond to the remaining part of activity 1.	5	
The human alimentary canal.	Ask pupils to label the diagram of the human alimentary canal.	5	
Summary	Review the names of parts of the alimentary canal. Hand out notes.	10	

Lesson Plan 12 - Digestion (In the mouth) (Individualistic)

What	How	Time	Materials
Introduction	Ask the pupils to describe what happens to say a piece of bread in the mouth when we eat it. They should write this at the back of their note books. Get any two pupils to each briefly describe what happens. Use those responses to develop an operational definition of digestion with the pupils. e.g. "the breaking down of large food molecules into smaller units that the body can absorb".	5 10	Chalkboard
Mechanical and chemical digestion.	Give each pupil a piece of bread to chew. (Hands should be thoroughly washed before handling food). Pupils should then proceed with activity 1. In a whole class discussion, summarise activity 1. Establish the concept of Mechanical and chemical digestion. Use a knife to cut a piece of bread into smaller pieces to demonstrate Mechanical digestion. Relate the sweet taste they felt when they chewed a piece of bread to a chemical change in the bread, hence chemical digestion.	10 10	Pieces of bread.
Effect of saliva on starch.	Use 2% starch solution to represent solution X. Each pupil should have about 3ml of this . Ask pupils to carry out activity 2, record their results and respond to the questions. Engage the whole class in a discussion of the results.	25 10	2% starch solution, 3 test-tubes per group, beakers, Bunsen burners, iodine, Benedict's solution and spotting trays.
Summary	Review Mechanical and chemical digestion.	10	

lesson Plan 13 - Digestion (Stomach) (Individualistic)

What	How	Time	Materials
Introduction	Explain that enzymes are proteins and as such are affected by heat and pH or acidity and alkalinity. Use universal indicator or litmus paper check the pH of saliva. Get pupils to infer the pH at which ptyalin would digest starch. Ask pupils what could happen if the pH is either too alkaline or too acidic. Get pupils to write this at the back of their notebooks and to compare their response with the result of activity 1.	7 5	Universal indicator paper or Litmus paper.
Factors affecting the activity of ptyalin.	Divide tasks among the pupils and let pupils do activity 1. Move around to ensure that pupils are on-task. Probe individual pupils to interpret and explain the results they are getting.	35	rubber bands, test-tubes, starch solution, beakers, tripod stands, gauze, Bunsen burners, iodine solution, Benedict's solution.
Digestion in the stomach - video show	Let the pupils read the questions. Play the video for pupils to watch. They should take notes. Pupils should then respond to the questions. Provision should be made for the pupils to see the video again say during afternoon studies if they so wish.	3 10 10	A ten minutes long video showing digestion.
Conclusion.	Review i. the pH in the stomach, ii. the effect of the pH on the activity of ptyalin. iii. pepsin as the enzyme active in the stomach iv. peristalsis.	5	

Lesson Plan 15 - Absorption (Individualistic)

What	How	Time	Materials
Introduction	Review digestion of carbohydrates, proteins and fats. Pupils should state where these are digested and state the end products of such digestion. Explain that at the end of digestion all the glucose, amino-acids, fatty-acids and glycerol are all in the ileum and need to be taken out of it to the cells where they are needed. This is achieved through absorption.	10	
absorption through a semi-permeable membrane.	Get the pupils around the demonstration table and set up the experiment with them. Pick on pupils to do various stages of the experiment. Draw a table on the chalkboard into which pupils will fill in their results. Ask pupils to fill in the results on the board. Discuss the results. Help pupils to reflect on the procedure if the results are not what they expect.	30 15	dialysis membrane, glass rods, starch solution, rubber bands, beakers, iodine solution, Benedicts' solution, Bunsen burners, tripods and gauze.
Structure of the small intestine	Ask each pupil to collect a bio-viewer and bio-strip. Demonstrate how to use a bio-viewer and ask the pupils to do Activity 2. Discuss activity 2 in a whole class discussion session.	5 15 5	Bio-viewers Bio-strip M17.
Conclusion	Review the process of absorption and how the small intestine is adapted for absorption.	5	

ANIMAL NUTRITION

Form Three

Lesson plans
(Competitive)

1996

Dear Teacher

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Students' ideas and how they could be mobilized to enhance learning are central. The teacher's role in this process is to facilitate the process of knowledge construction by the pupils. A classroom environment in which students are free to ask questions, respond to questions without feeling threatened and make suggestions needs to be created to encourage the development of the pupils own ideas.

The teacher's guides are meant to show typical responses to the questions posed. They are not in anyway exhaustive. Student responses therefore, need to be very carefully considered with a view to develop them to scientifically accepted ideas. This can in part be achieved if the teacher is able to reflect on the content of the pupils' responses. Reflective practice therefore, should underpin all activities in exemplary classes.

It is necessary for you to reflect on the content and pedagogical strategies before the lesson, and in addition to these, reflect on the classroom interactions during and after the lesson.

The pupils' workbooks are their own property. They should be encouraged to write in them as well as use them effectively for learning.

Lesson Plan 1 - Feeding (Competitive)

What	How	time	Materials
Introduction Nutrition	Explain nutrition as the relationship between organisms and their food i.e. How the organism obtains food, what it feeds on, how it feeds, the effects of food on its health, population and growth and how best it is suited to feed on that food. Ask pupils to do activity 1 in the workbook. Go around the class and discuss with pupils who need your help. Allow for ingenuity and full expression of their views. Ask thought-provoking questions e.g. Why should organisms feed? etc. Verbally reward the pupils who are doing well. Ensure that pupils know how they are doing relative to others.	5 15	
Different ways of feeding	allow students to spend 10 minutes on each of activities 2,3,4,5 and 6. Again go round and encourage them to reflect on their ideas.	50	
Conclusion	Summarize the main points a) plants and animals need food. b) plants make their own food. c) animals depend on plants and on other animals for food. d) living things obtain food in different ways e) animals have developed structures that enable them to feed on their type of food.	10	

Lesson Plan 2 - Feeding continued (Competitive)

What	How	Time	Materials
Introduction	Ask questions about the previous lesson. e.g. What did we learn about ways in which certain organisms feed or Thomo found a bird with a long thin beak. He thought it fed on meat. Would you agree with him? Why? Allow for discussion and exchange of views. Acknowledge valid and invalid answers.	10	Chalkboard
The growth, reproduction and the health of organisms depend on the availability of food.	Open a debate to explore pupils' ideas about inter dependence of organisms e.g. "Agricultural demonstrators have recently been going around advising farmers not to keep too many cattle on one piece of land" Do you agree or disagree with this idea? Divide the class into those who agree and those who do not and open a debate. Note on the board all the points groups raise which would be used later to build the notion of inter dependence of organisms. And reward the groups for reflective contributions to the debate. Competitive groups to make observations and notes. Use these ideas to develop: i. relationship between food and population growth. ii. energy transfer along the pyramid of numbers.	15 10	Chalkboard.
Relationship between organisms their food.	Take pupils out to a piece of grassland on the school grounds (only five minutes walk). Define the perimeter in which the search will be done. It should be such that no group will be out of sight. Let each group follow its own path and do activity 1. (Snakes, spiders and scorpions if spotted, should be treated as lethal)	35 (5 min. for wal-king)	Workbooks, insect nets, hand lenses.

What	How	Time	Materials
Conclusion.	Use the question and answer to reflect on the i. the relationship between the amount of food and the number of organisms feeding on it. ii. the relative physical size of organisms that feed on others as compared to those that are fed on. Reward groups verbally for active participation.	10	

Lesson Plan 3 - Classes of nutrients (Competitive)

What	How	Time	Materials
Introduction	Link current lesson with the previous one. e.g. We learnt that living things need food. Give examples of some animals and the food they eat. Do animals need only one type of food? Give examples of animals that eat a variety of food. What do they eat? Give appropriate praise and verbal reward to the pupils for good responses.	10	halkboard
Classes of food.	Ask groups to list at least ten different types of food they eat. Why do they need different types of food? Reward pupils for reflective thinking. Create a competitive atmosphere by making comments on the progress of the groups e.g. group "apple" or "pear" has already listed seven types of food. When will you catch up?	10	chalkboard
	Pick on several pupils from the groups to report their responses. Summarise these on the chalkboard.	10	
	Use the pupils' responses to develop the concept of classes of nutrients. e.g "some types of food give us energy" should be followed up with questions like - what are the examples of such types of food? Examples of fats and carbohydrates may be given by the pupils. Using these examples, introduce fats and carbohydrates as two groups of food that give us energy.	15	

What	How	Time	Materials
Examples of food in the various food classes.	Groups should be assigned one of the six groups of food. Each group should have a piece of manila paper and two old magazines. Each group should cut out pictures of type of food assigned to them and paste them on the manila paper and label it. Under each picture should be the name of the food. Reward the groups for correct entries by praissing the group. Make comments on the rate of work amongst the groups. Pin up the posters at the back of the class.	15 2	Manila paper Glue sticks, markers, pairs of scissors,old magazines, drawing pins or bostik.
	Arrange pupils such that all can see the display. Summarise the examples of different classes of nutrients.	3 10	
Summary	Discuss the main points of the lesson.	5	

Lesson Plan 4 - Food tests (Starch) (Competitive)

What	How	Time	Materials
Introduction	Lecture - Explain that it is possible to test for the nutrients contained in food. Ask pupils to suggest a reagent that can be used to test for starch. Ask pupils to put a drop of iodine on a white tile and to describe the colour of iodine.	8	iodine solution, white tile
Identifying a test for starch	Each group should have $2cm^3$ of one of the following solutions: A= 1% albumen solution, B=10% glucose solution, C=1% starch solution, D=Cold water, E=Hot water on their tables. Pupils should not be told solutions A-E are. Pupils should tasks among themselves and perform them simultaneously to save time. They should record the colours as they perceive them . Do not tell them the colours. They should then respond to the questions that follow. Get groups to compete for good results and finishing first. Draw a table on the chalkboard for the groups to report their findings. Groups which finish first for each solution tested should fill their results into the table on the chalkboard. Each for one of the solutions tested Lead a discussion to help pupils compare and resolve disparities between their results. You should ask questions like " Do we all get the same results? Which results are not the same as others? Are they wrong results? Why? Maintain a competitive atmosphere and verbally reward good work.	5 5 5 10 7	1% albumen solution, 10% glucose solution, 1% starch solution, iodine solution, droppers, test-tubes Chalkboard

What	How	Time	Materials
conditions under which iodine reacts with starch	Divide the tasks among groups of pupils and let them carry out activity 2. They should do their activities simultaneously to save time. Ask them to respond to the questions that follow activity 2.	8 5	1% starch solution, Bunsen/ spirit burner
Testing for the presence of starch.	Divide the tasks among groups of pupils. Add water to food samples which are already in powder form. Groups should test these while you are preparing the remaining food samples. Reward groups for observing safety rules, good results and good working rate.	20	Potato, bread, maize meal, banana, apple, dried milk, sorghum meal, phane.
Conclusion	Wrap up the main points of the lesson in a question and answer session. Collect workbooks for marking.	7	

Lesson Plan 5 - Food tests (Glucose) (Competitive)

What	How	Time	Materials
Introduction	Review the previous lesson. Ask pupils to look at the poster for carbohydrates produced in the other lesson. Ask them which ones of those are sweet. These are sugars. Ask them to give examples of the sugars they know. Which sugar do they use during athletic sports? Tell pupils that it is possible to test for the presence of glucose. Ask them to suggest a reagent that could be used to do this. Introduce Benedict's solution and ask the pupils to describe its colour.	10	Benedict's solution
Benedict's solution changes colour when glucose is present.	Divide the tasks among the pupils. Ask the pupils to collect the appropriate solution among solutions A - E together with all the necessary materials.	5	
	Pupils should then start working. Encourage them to compete for accuracy and speed.	10	
	They should then respond to the questions that follow.	5	
	Draw a table the board on which the pupils will report their findings. Ask one member in the group that finished first to fill in the results of the group in the table on the chalkboard for the solution they tested. As others finish they should do likewise.	5 5	
	Lead a class discussion of the results. Verbally reward pupils for good responses. Pupils should raise their hands in order to answer. Select only those raising their hands first.		

What	How	Time	Materials
Testing food samples for the presence of glucose.	Add water to the food samples that are already in powder form. Crush those that are not in powder form in a mortar with a bit of water. Assign each group particular foodstuffs to test. Draw the table on the board and ask the groups to fill in their results as soon as they finish. The group which finishes first should fill in its results on the board. Discuss the results with the whole class. Pupils should now copy the results from the board.	15 3 10 7	
Summary	Summarise the main points of the lesson.	5	

Lesson Plan 6 - Food tests (Proteins) (Competitive)

What	How	Time	Materials
Introduction	Review test for glucose. Ask for the examples of food containing glucose. Introduce the pupils to the reagents used in the Biuret test. Explain the precautions to be taken when handling sodium hydroxide.	10	Copper sulphate, sodium hydroxide.
Identifying a test for proteins.	Ask pupils to collect the materials needed. Divide tasks in activity 1 among competititve groups and ask them to start working. Each group should predict the colour changes it expects when the named food stuffs in the worksheet are tested using the Biuret test. Lead a class discussion and let the groups explain the reasons for their prediction. Pick groups who finish first and encourage them to compete for good answers.	5 15 5 10	NaOH, $CuSO_4$, A=1% albumen, B=10% glucose, C=1% starch, D= cold water E= hot water. Test-tube racks and holders.
Testing food for proteins.	Assign each group particular foodstuffs to test. Liquid foods samples can be tested directly. Solid foodstuffs should be crushed in a bit of water.	15	NaOH, $CuSO_4$, fish, lean meat, mealie-meal, milk, mophane caterpillar, sorghum meal, cooking oil, test-tubes, test-tube holders and racks.
Summary	Discuss the results in a whole class discussion. Give notes.	10 10	

Lesson note 7 - Food tests (Fats) (Competitive)

What	How	Time	Materials
Introduction	Ask pupils to suggest how they could test for fats. Ask members of the groups to quickly describe their responses. Look out in the pupils' responses for elements of the greasy spot test and the emulsion test. Note the points that could be used to develop the idea of greasy spot test and the emulsion test on the board. Encourage groups to out compete each other and stick stars on the work of groups which present plausible tests. Use these ideas to develop the concept of the greasy spot and demonstrate the greasy spot test.	10 20	Cooking fat, filter paper.
Identifying a test for fats - the emulsion test.	Pupils should collect materials for their competitive groups and do activity 1 and respond to the questions that follow. Go round discussing withgorupd and verbally reward and praise those who are doing well and making good progress. Encourage group competition e.g. Group "Pear" is well ahead. When will group "Banana" catch up? Use the question and answer method to summarise this.	20	Cooking oil, alcohol, test-tubes.
Testing food samples for fats.	Assign tasks to the competitive groups and let them continue with activity 2. Draw a table on the chalkboard and get the groups which finish first to fill the results for each test into it. Discuss the results with the class through a question and answer method.	20	alcohol, mortar, pestle, test-tubes, filter funnel, filter paper, retort stand, boss heads and clamp, ground nuts, cheese, potato, meat, mophane caterpillar.

What	How	Time	Materials
Conclusion	Review the two tests for fats. Ask pupils to give example of food rich in fats.	10	

Lesson Plan 8 - Dentition (Competitive)

What	How	Time	Materials
Introduction	Explain that animals in most cases get their food as materials that cannot readily be used by the body. Such food materials need to be broken down to smaller units that can be conveniently absorbed by the body. Ask pupils to give examples of food which may need to be broken down to smaller pieces when we eat and to describe how such food is broken down in the mouth. Summarise the responses and emphasise the role of teeth in mechanical digestion.	2 5 3	
Importance of the teeth.	Pupils in competitive groups should suggest the importance of teeth. Groups should indicate their intention to respond by raising their hands. Summarise this by allowing groups to say their responses. Responses may include i. teeth adorn us. ii. they maintain the shape of the mouth. iii. can be used for fighting and scaring away enemies. chewing etc.	5 5	
Identifying different types of teeth.	Competitive groups should use mirrors to do activity 1.i). After this they should continue with the rest of activity 1. Go round discussing with groups. Openly reward those who are doing well. Discuss the responses with the pupils. Limit your role to reflecting discrepancies in their responses and let them deal with that.	5 30	
Relating dentition to diet.	Pupils should do activity 2 and respond to the questions.	10	Skulls from goats and sheep.
Summary	Summarise the lesson and let the pupils prepare for Activity 1. lesson 10.	10	
Notes	Give brief notes.	5	

Lesson Plan 9 - Dental formulae (Competitive)

What	How	Time	Materials
Introduction	Review last lesson. Ask pupils the number of the different types of teeth in an adult with a full set and to describe their shapes . Pick on the pupils whose hands are up to answer the questions	3	Chalkboard
	Get pupils in the competitive groups to think of a way in which they can briefly and clearly represent the number and types of their teeth to a friend. Go round looking at the pupils' work and verbally reward groups that are making good progress.	7	
	Ask groups which have done it to present their findings on the board.	5	
	Develop the ideas of the pupils to develop the concept of dental formula. e.g. some pupils could have used letters like C, I, P. and M in their formulae.	10	
Dental formula	Let the competitive groups of pupils do activity one and answer the questions in the process. Monitor the progress progress of the groups and verbally reward good work. Competitive groups should not in any way help each other.	20	
Dental formula is related to the diet of the organism.	Let the pupils do activity 2 and answer the questions. The first group to finish should write the answers on the Chalkboard.	15	
	Pick pupils from the groups to present their responses on the board. Allow for comments and questions.	10	
Summary	In summary review the steps involved in deriving a dental formula.	10	

Lesson Plan 10 - Tooth Structure (Competitive)

What	**How**	**Time**	Materials
Introduction	Explain the concept of milk and permanent teeth. Use the pupils existing ideas in this process. Each competitive group of pupils should have a tooth from each of the beakers set up in the last lesson and continue with activity 1. Go round looking at the pupils' work. Verbally reward good work such that the group is aware of its performance relative to others. Get a pupil from each competitive group to describe the hardness of a tooth in the hydrochloric acid as opposed to those in water and saliva. Use this observation to explain the concept of tooth decay.	10 20 5	Teeth from the test-tubes prepared in the last lesson.
Care for teeth	Pupils should now do activity 2. Allow for ingenuity and experiences in this discussion. Reward pupils verbally for creativity and good work. Lead a whole class discussion of activity 2. Let the pupils freely discuss plausible methods they have suggested and consider the advantages and disadvantages of those.	15 20	
Summary	Review the structure of the tooth and care of teeth.	10	

Lesson Plan 11 - The Alimentary Canal (Competitive)

What	How	Time	Materials
Introduction	Ask competitive groups to describe the path followed by food from the time it is swallowed to the time it leaves the body through the anus. The group that finishes first should write the answer on the chalkboard answer. Give verbal rewards for correct responses. Use their responses to define the alimentary canal as a continuous muscular tube running from the mouth to the anus.	10	
The alimentary canal - rat.	Arrange pupils around the dissected rat so that all can see. Pick on some pupils at random and ask them to identify parts of the alimentary canal that they recognise. Give verbal rewards for correct responses and continue to create a competitive environment. Ask one pupil to count the incisors on the upper and lower jaws, another to count canines etc. Write these on the board. Get pupils to locate the trachea and the oesophagus. Then to go back into competitive groups and suggest their functions. Ask competitive groups to respond to Activity one, questions 2a-c.	20 15	Dissected rat, chalkboard
Small and large intestines, caecum, rectum and anus.	With pupils around the demonstration table, ask them to identify the small intestines, large intestine, caecum, rectum and the anus. Ask pupils to identify the liver and pancreas. On the liver, pupils should locate the gall bladder. Cut the gall bladder and get a student to describe the colour of bile. Explain the role of the liver in the digestion of fats. Get each group to respond to the remaining part of activity 1.	5 10 5	
The human alimentary canal.	Ask competitive groups to label the diagram of the human alimentary canal.	5	

What	How	Time	Materials
Summary	Review the names of parts of the alimentary canal. Hand out notes.	10	

Lesson Plan 12 - Digestion (In the mouth) (Competitive)

What	How	Time	Materials
Introduction	Ask the competitive groups of pupils to describe what happens to say a piece of bread in the mouth when we eat it. Get two groups which finish first to briefly describe what happens. Pupils should show their intention to answer by raising their hands. Pick on the one who's hand is up first. Use those responses to develop an operational definition of digestion with the pupils. e.g."the breaking down of large food molecules into smaller units that the body can absorb".	5 10	Chalkboard
Mechanical and chemical digestion.	Give each pupil a piece of bread to chew. (Hands should be thoroughly washed before handling food). Cooperative groups should then proceed with activity 1. Go around and verbally reward groups which are doing well. In a whole class discussion. summarise activity 1. Establish the concept of Mechanical and chemical digestion. Use a knife to cut a piece of bread into smaller pieces to demonstrate Mechanical digestion. Relate the sweet taste they felt when they chewed a piece of bread to a chemical change in the bread. hence chemical digestion.	10 10	Pieces of bread.
Effect of saliva on starch.	Use 2% starch solution to represent solution X. Each competitive group should have about 3ml of this . Ask groups to carry out activity 2. record their results and respond to the questions. Engage the whole class in a discussion of the results. Maintain a competitive environment by verbally rewarding groups and making it clear to the groups that they should compete to finish and to answer the questions.	25 10	2% starch solution. 3 test-tubes per group. beakers. Bunsen burners. iodine. Benedict's solution and spotting trays.
Summary	Review Mechanical and chemical digestion.	10	

Lesson Plan 13 - Digestion (Stomach) (Competitive)

What	How	Time	Materials
Introduction	Explain that enzymes are proteins and as such are affected by heat and pH or acidity and alkalinity. Use universal indicator or litmus paper check the pH of saliva. Get pupils to infer the pH at which ptyalin would digest starch. Ask pupils what could happen if the pH is either too alkaline or too acidic. Get competitive groups to discuss this and to compare their responses with the result of activity 1.	7 5	Universal indicator paper or litmus paper.
Factors affecting the activity of ptyalin.	Divide tasks among the groups and let them do activity 1. Move around to ensure that groups are on-task. Probe groups to interpret and explain the results they are getting. Verbally reward the groups for a good working pace, good working habits and good results.	35	rubber bands, test-tubes, starch solution, beakers, tripod stands, gauze, Bunsen burners, iodine solution, Benedict's solution.
Digestion in the stomach - video show	Let the pupils read the questions. Play the video for pupils to watch. They should take notes. Pupils should then respond to the questions. Provision should be made for the pupils to see the video again say during afternoon studies if they so wish. Look at the work of those finishing first and praise good work.	3 10 10	A ten minutes long video showing digestion.
Conclusion.	Review i. the pH in the stomach. ii. the effect of the pH on the activity of ptyalin. iii. pepsin as the enzyme active in the stomach iv. peristalsis.	5	

Lesson 14 - Digestion (Small intestine) (competitive)

What	How	Time	Materials
Introduction	Explain to the pupils that the digestion of carbohydrates. proteins and fats is completed in the small intestines. Let pupils do activity one. Summarise activity 1 through a whole class discussion. Pick pupils at random from the groups to answer the questions. Reward competitive groups verbally for correct responses. Establish food molecules which have been partially digested and still need further digestion, and those whose digestion will start in the small intestine.	15 10	Chalkboard Workbook
The role of the liver and the pancreas in digestion.	Explain the role of the liver and the pancreas in digestion. Mention the enzymes contained in pancreatic juice only. Leave out the enzymes produced in the intestinal juice. Competitive groups should now do activity 2. Assign pupils either to do an advert for the liver or for the pancreas. Give out sheets of Manila paper for groups to write on. Create a competitive atmosphere by making comments like "Well done group "Pears". This group has already finished activity 1 a) and are now on activity 1b". Pick out five good adverts in terms of i. describing what is produced in the organ and ii. what it does. Stick some stars to these. Ask pupils to stick their "adverts" on the wall of the classroom or laboratory. And summarise the activity two in a whole class discussion of the "adverts"	15 15 10	Manila paper. markers. bostik.

What	How	Time	Materials
Summary of digestion - "who is who?"	Stick up on the board and adjacent walls six labels written mouth, stomach, liver, pancreas, colon, and small intestines. On the teacher's table put up side down, phrases like " I store bile; I produce trypsin; ptyalin digests starch; absorption occurs here; digestion of fats starts here; I am an acidic environment etc." Pick pupils systematically from the groups such that all the groups get an equal chance to respond.. A pupil should come, pick an up side down phrase, show it to his/her group which will decide quickly where it should go and stick it under the appropriate organ. Praise groups for correct and fast decisions.	15	Manila paper, markers, Bostik.
Summary	Review the role of liver and pancreas and digestion in the small intestines.	5	

Lesson Plan 15 - Absorption (Competitive)

What	How	Time	Materials
Introduction	Review digestion of carbohydrates, proteins and fats. Pupils should state where these are digested and state the end products of such digestion. Explain that at the end of digestion all the glucose, amino-acids, fatty-acids and glycerol are in the ileum and need to be taken out of it to the cells where they are needed. This is achieved through absorption.	10	
absorption through a semi-permeable membrane.	Divide pupils into competitive groups of five and let each group perform the experiment. Praise groups when they achieve their tasks. Draw a table on the chalkboard into which competitive groups should fill in their results. Ask reporters from eaach group to fill in the results on the board. Discuss the results. Verbally reward groups for their contributions to the discussion. Help pupils to reflect on the procedure if the results are not what they expect.	30 15	dialysis membrane, glass rods, starch solution, rubber bands, beakers, iodine solution, Benedicts' solution, Bunsen burners, tripods and gauze.
Structure of the small intestine	Ask each competitive group of two or three pupils to collect a bio-viewer and bio-strip. Demonstrate how to use a bio-viewer and ask the groups to do Activity 2. Discuss activity 2 in a whole class discussion session. Let the groups compete to respond to the questions you pose.	5 15 5	Bio-viewers Bio-strip M17.
Conclusion	Review the process of absorption and how the small intestine is adapted for absorption.	5	

ANIMAL NUTRITION

Form Three

Pupils' Workbook

1996

Dear student

This work book is designed to help you learn animal nutrition in a meaningful way. It is hoped that it will help you to think about what you are doing. In this sense you will have to explain a lot of the things that you will be doing. When explaining, you are not expected to reproduce things that you have heard or necessarily read from the books. Rather, you are expected to use the evidence and information available to you to support your arguments.

You may be required to work as an individual or in groups. Whatever the case may be, you will need to fully participate in carrying out the tasks assigned to you.

This is your workbook. You are free to write your responses into it. If you want, you may fill in the answers in pencil so that as you reflect on your work or exchange ideas with others or your teacher, you may change your mind and respond differntly.

Science is fun. Enjoy it.

Lesson 1 - Feeding mechanisms.

At the end of the lesson, you should be able to:

1. Describe feeding in fluid feeders, amoeba and grasshopper.
2. Discuss feeding adaptations in fluid feeders, amoeba and grasshopper.

Feeding.

An important characteristic of all living things (organisms) is that they feed. Green plants manufacture thier own food and hence are called autotrophic. Animals are called heterotrops because they cannot manufacture the organic materials they need. They take in these organic materials as food in a variety of ways (see table 1).

Activity 1.

Think of five examples of organisms feeding and fill the table below.

Example of feeding.	What is feeding?	What is it feeding on?
A lion eating a cow	lion	cow

Choose any two organisms from Table 1 and describe how they feed.

a)

b)

Do plants feed too?

If yes,
a) what do they feed on?

b) How do they feed?

Do all living things (organisms) feed the same way?

Think of two organisms that do not feed in the same way.

a)

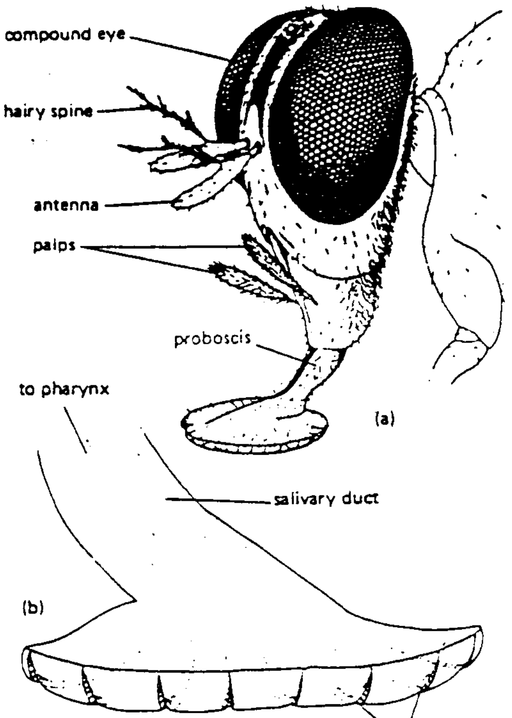
b)

What are the differences between the way organisms (a) and (b) feed?

Feeding by organism (a)	Feeding by organism (b)

Activity 2.

Look carefully at the mouth parts of a house fly.



(a) Lateral view of head X15
(b) Section through base of proboscis X45

Mouthparts of a housefly, Musca domestica

Suggest what a housefly uses for feeding?

In what state of matter do you think the food should be when the house fly takes it in?

a) solid
b) liquid
c) gaseous

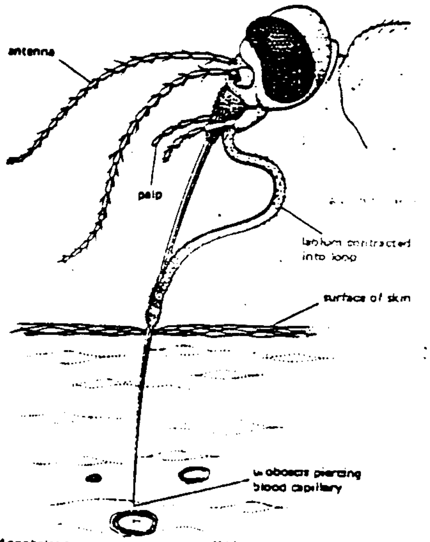
Why?

Describe how a housefly feeds.

Houseflies can easily transmit deseases to man. Explain how this is related to the way they feed.

Activity 3.

Look carefully at the mouth parts of a mosquito.



Anopheles mosquito: mouthparts X 15

Suggest what a mosquito uses for feeding?

What does a mosquito feed on?

Is a mosquito a fluid feeder?

How does it feed?

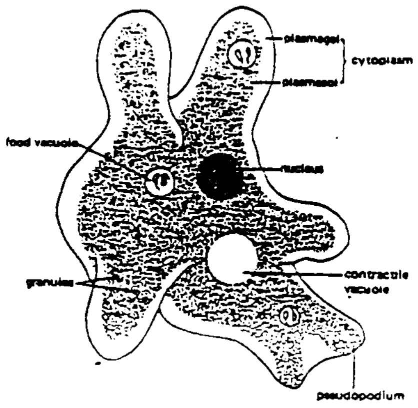
In what ways is feeding in a mosquito and a housefly similar?

How are mosquitoes and houseflies adapted for feeding on fluid food?

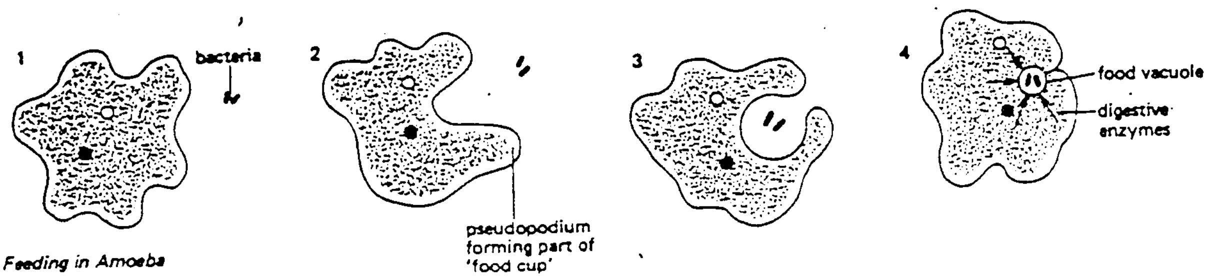
A mosquito and a housefly are examples of______ _______.

Activity 3.

An amoeba is a one-celled animal. Amoeba also feeds.



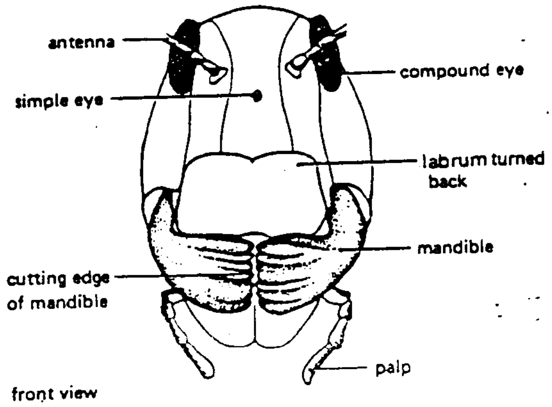
Amoeba proteus X300



Feeding in Amoeba

Carefully study the sequence of activities in fig. 3 above describe how an amoeba feeds.

Activity 4.



Mouthparts of short-horned grasshopper X5

What do grasshoppers feed on?

Describe how they feed?

How are they adapted for their kind of food?

What do they use to cut their food?

What could they be using to hold the food when they cut it?

Lesson 2- Feeding

In this activity, you are going to study the feeding relationship among organisms. A lot of animals and plants can be found in the grassland on your school compound. Living things will always live where they will be able to hide away from enemies, where they will be protected from extremes of h_____ and c_____ and where they will find f_______.

Read through the workbook carefully before you go into the field.

Walk carefully through the grass. Look for living things and record them in the table in your workbook.

Name of organism	Tallies (Total)	Where was it found?	What does it feed on?

Choose any one organism from your table and answer the following questions about them.

1. What is the animal you have chosen?

2. What does it feed on?

3. At the place where you found the organism, was there anything it can feed on?

   How much of it?

4. How do you think the amount of food available affects the number of organisms in that area?

5. What might happen to the number of the organism if the amount of food is reduced?

6. Compare the number of organisms that feed on others with those they feed on. What do you find?

Lesson 4 - Food Tests (Starch)

At the end the lesson, pupils be able to:

1. Suggest a procedure to identify a reagent that can be used to test for starch.

2. Suggest a procedure to test whether starch will always react with iodine.

3. Identify rich sources of starch using iodine solution.

Activity 1 - Identifying a test for starch.

Label five test-tubes 1-5
Put 20mm of
1. solution A into test-tube 1
2. solution B into test-tube 2
3. solution C into test-tube 3
4 solution D into test-tube 4
5 solution E into test-tube 5

To each test-tube, add three drops of iodine solution using a dropping pipette. Carefully observe the colour changes. Record your results.

Substance	Observation
Solution A	
Solution B	
Solution C	
Solution D	
Solution E	

i. Which of the five samples of food tested produced a particular colour with iodine?

ii. What colour was produced?

iii. What could substances A-E be?

iv. What could the substance that produced a colour change with iodine be?

v. Why do you think so?

vi. Suggest how you would confirm this to yourself.

vii. What could iodine solution be used as a test for?

viii. Suggest how you would show that your idea above works?

Experiment 2. Does iodine always give a colour change with starch?

(a) Label five test-tubes 1-5.

(b) (i) Pour about 20mm solution F into test-tube 1. Using a test-tube holder, heat this solution over a small Bunsen flame until it boils. Shake the tube gently while heating.

(ii) Add 1 drop of iodine solution.

(iii) Cool the test-tube under the tap until it feels cold or only slightly warm. If no change occurs on cooling, add another drop of iodine.

(c) Place about 2mm powder G in test-tube 2 and add three drops of iodine solution.

(d) Place about 2mm powder G in test-tube 3, add about 20mm cold water and shake vigorously with your thumb over the mouth of the tube. Add one drop of iodine solution.

(e) Pour about 20mm cold solution H into test-tube 4 and add one drop of iodine solution.

(f) Pour about 20mm of cold solution H into test-tube 5 and add about 5 drops of iodine solution.

Hold the tubes, in pairs, up to the light and shake them gently to compare the colours. Record the results in your notebook as follows:

Substance	Colour change
(b) (i) Hot solution F	
(ii) Cooled solution F	
(c) Powder G	
(d) Powder G in cold water	
(e) Solution H + 1 drop of iodine	
(f) Solution H + 5 drops of iodine	

i. What do the colour changes suggest is present in substances F,G and H?

ii. What is different in the samples of solution F?

iii. What is different in the samples of powder G?

iv. What is different in the samples of solution H?

v. Under which conditions did iodine solution react to produce the observed colour changes?

vi. What would you conclude from the results of this experiment?

Activity 3 - Testing food for the presence of starch.

The iodine test is a sensitive test, to make sure that you get correct results, thoroughly clean the test-tubes if you are going to re-use them. The mortor and pestle to should be thoroughly cleaned to avoid contamination of one food sample with the other.

(a) Label eight test-tubes 1-8

(b) Your teacher will crush eight types of food in a mortar with a bit of water.

(c) Pour about 10 cm^3 of each type of food sample in a clean test-tube. Using a test-tube holder, heat the mixture in in each test-tube in a small flame of the Bunsen burner till it boils for a few seconds. Shaking each test-tube gently all the time.

(d) Cool each tube under a running tap.
(e) Add five drops of iodine solution to each tube.
(f) Record your results.

Food sample	Observation	Interpretation of result
1. Potato		
2. Maize meal		
3. Bread		
4. Banana		
5. Apple		
6. Dried milk		
7. Sorghum raisins meal		
8. Mophane caterpillar		

Lesson 5 - Food Tests (Glucose/Reducing Sugar).

At the end of the lesson, pupils should be able to:

(i) Identify and describe a test for reducing sugars.

(ii) Suggest sources of glucose using the Benedict's solution test.

Activity 1 - Identifying a test for reducing sugars.

(a) Label five test-tubes 1-4
(b) Put 20mm of
solution A into test-tube 1
solution B into test-tube 2
solution C into test-tube 3
solution D into test-tube 4

(c) To each tube add about 10mm Benedict's solution.

(d) Using a test-tube holder and directing the test-tube mouth away from the people, heat each test-tube gently in a small bunsen flame (a spirit burner is preferable) shaking the tube all the time. When the mixture boils, stop heating.

(e) Record the results.

Solution	
1. A	
2. B	
3. C	
4. D	

i. Which of the substances tested reacted with Benedict's solution?

ii. Describe the colour changes produced when Benedict's solution reacts with the substance present in this test-tube.

iii. What could be present in the test-tube(s) that produced a colour change?

iv. For what can Benedict's solution be used as a test?

Activity 2 - Testing food sample for the presence of a reducing sugar.

(a) Prepare a water bath by half filling a beaker with water (your teacher will provide boiling water for this purpose to save time) and heating it on a tripod and gauze over a bunsen burner. When the water boils, turn the flame down so that boiling point is just maintained.

(b) Label eight test-tubes 1-8

(c) Your teacher will give you crushed food samples mixed with a bit of water.

(d) Pour about 20mm of the crushed mixture into a test-tube and add about 10mm Benedict's solution.

(e) Place the test-tube in the water bath for 5-10 minutes and record your observations.

(f) Repeat the test from the remaining food samples.

Food sample	Observation	Int. of results
1. Potato		
2. Maize meal		
3. Bread		
4. Banana		
5. Apple		
6. Dried milk or milk		
7. Raisins		
8. Mophane caterpillar		

Which food samples are rich sources of sugars?

iii. So what nutrient is present in the test-tube that gave a purple colour with the Biuret test?

iv. Predict what colour change would occur if the following food samples were tested with Biuret test..

Substance	Predicted colour change
Lean meat	
Mealie meal	
Fish	
Soya beans	
Mophane caterpillar	
Milk	

Activity 2 - Testing Food Samples for Protein

(a) Label eight test-tubes 1-8

(b) If the food is solid, your teacher would have crushed it for you in a mortar in a bit of water (if it is liquid, simply take 20mm of it) into a test-tube.

(c) Pour about 20mm of the crushed mixture into a test-tube.

(d) Add about 5mm of sodium hydroxide solution.

(e) Add about 5mm of dilute copper sulphate solution and shake the tube gently sideways to mix the contents.

(f) Put back the test-tube into the rack, wait for a few seconds and record the observations.

Food sample	Observation	Interpretation
Lean meat		
Fish (Sardines)		
Mealie-meal		
Milk		
Mophane caterpillar		
Sorghum meal		
Cooking oil		

In which food samples are proteins present?

If a food sample gives a purple colour with the Biuret test, does it mean that the only foodstaff it contains is protein?

Lesson 7 - Food Tests (Fats)

At the end of the lesson, pupils should be able to:

1. Suggest and describe a test for fats.

2. Give examples of food services rich in fats.

Activity 1 - The Emulsion Test - Identifying a test for fats.

N.B. All apparatus must be dry. Extinguish all flames.

(a) Label test-tubes 1 and 2.

(b) Pour 20mm of alcohol into each of test-tubes 1 and 2.

(c) To test-tube 1 add one drop of vegetable oil, and shake the tube sideways until the oil dissolves in alcohol.

(d) Now add 20mm of water to each of test-tubes 1 and 2.

(e) Record your observations.

Substance	Result when added to water
Oil dissolve in alcohol	
Alcohol alone	

What was the only difference between the contents of test-tube 1 and 2?

What was the visible difference between the contents of test-tubes 1 and 2 after water was added to them?

What substance contained in one of these test-tubes could be responsible for this visible difference?

Activity 2 - Testing Food Samples for Fats.

All apparatus must be dry. Put out all flames.

(a) Label test-tubes 1-5.

(b) Cut a small sample of food (not more than 5mm cube).

(c) Crush the sample in a dry mortar and pestle with about $10cm^3$ alcohol (iso-propanol).

(d) Filter the crushed mixture into a dry test-tube.

(e) Pour the filtrate into a test-tube containing about 1cm of water.

(f) Examine the liquid and record whether it is clearly, slightly cloudy or cloudy.

Food	Appearance of filtrate when added to water	Interpretation
Ground nuts		
Cheese		
Potato		
Meat (bilton)		
Mophane caterpillar		

Which food items tested above contain fats?

If the filtrate was cloudy before adding to water, would this give reliable results.

What could be the cause of a cloudy filtrate?

If a clear filtrate, when added to water, produces a cloudy liquid, what can be the conclusions?

Lesson 8 - Dentition

At the end of the lesson, pupils should be able to:

(i) Discuss the importance of the teeth.

(ii) Identify different types of the teeth.

(iii) Discuss the functions of each type of teeth.

Activity 1 - Identifying the different types of teeth.

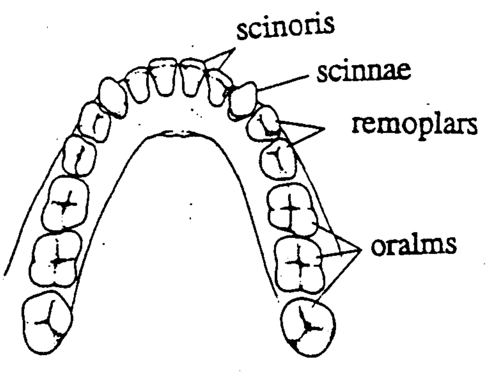
i. Using a mirror, look at your teeth. If there are no mirrors, look at a friends teeth. (Note: Do not put your finger into your friend's mouth).

ii. How many teeth are there altogether?

iii. Are all the teeth the same size and shape?

A full set of teeth in a human being consist of four different types of teeth.

Look at the set of teeth below.



iv. Which features of the teeth can you use to place the teeth into different groups.

v. Re-arrange the letters opposite each group of teeth to get the correct name.

The four kinds of teeth are ________, ___________, _____________ and _____________

vi. How would you best describe the shape of each type of teeth?

Name of tooth	Description

Teeth enable us to feed on a variety of food. For instance, we can bite, chew, and tear food with our teeth.

When you eat an apple, which type of teeth do you use?__________________, _________________ and ___________________

Suggest the functions of these teeth in feeding.

When you eat a piece of meat, which teeth do you use most?

Suggest the functions of these teeth in feeding.

Activity 2 - Relating teeth to the diet of an animal.

The teeth are adapted for particular diets. An animal that does not feed on meat does not need teeth that are used for feeding on meat. Teeth can therefore, be used to predict the diet of an animal.

Carefully examine the teeth on the skull provided.

Record the number and types of teeth present.

Suggest the diet such an animal might feed on.

Explain your answer above.

N.B. Activity 1, lesson 10 will need to be set up in advance. Read through it and set the time to it up.

Lesson 9 - Dental Formulae

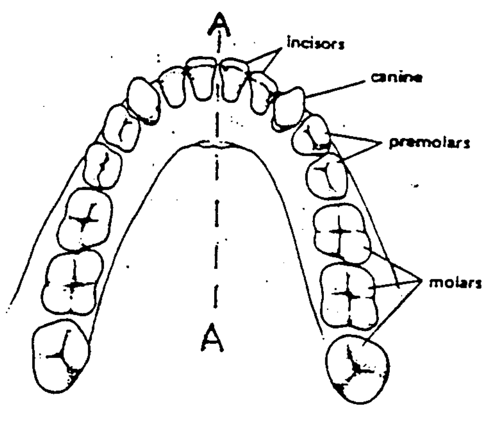
At the end of the lesson, pupils should be able to:

1. Produce dental formulae for the skulls provided. (Where there are no skulls, good diagrams/pictures should be used).

2. Relate dental formulae to diet.

Activity 1

Look carefully at figure 1 below.



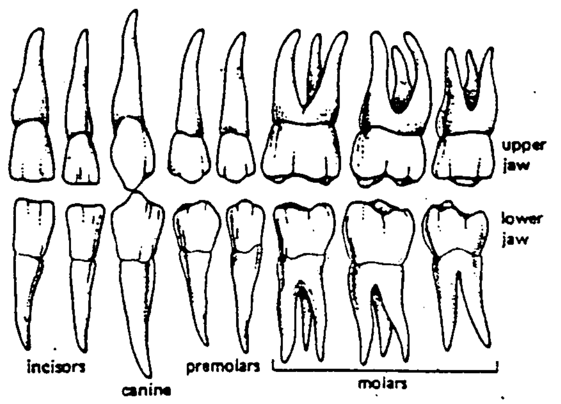
A human dental arcade X1

What can you say about the teeth on the left and on the right of line A-A?.

Mammals are bilaterally symmetrical i.e. they can be cut into equal halves. Hence, the teeth on the right hand side of the head are ______ ____________ as those on the left hand side.

The dental formula represents the numbers of each kind of teeth on the upper and lower jaws of a mammal. It represents only one half of the head since the other will be the same.

Carefully study the figure 2 below. It represents human teeth.



Lateral view of human teeth X 1
After R. H. Stone and A. B. Cozens. New Biology for West African Schools. Longman Group Ltd.

Does the diagram show all the teeth in the mouth?

Do the teeth represent the teeth in the upper and lowe jaws?

In a dental formula, letters are used to represent the different types of teeth. I= incisors, C = canine, P = pre-molar, M= molar.

Following the letter is a fraction. On the top is the number of teeth of that type in the upper half of the jaw. The bottom number is the number of teeth on the botton half of the jaw.

Example $1\frac{1}{1}$ means that there is one incisor on the upper half of the jaw and one incisor on the lower half of the jaw.

How many incisors are there in the whole set of teeth in the example above?

Write a dental formula for figure 2 above.

1 _____, C _____, P _____, M _____.

How many incisors does the full set have?

How many canines does the full set have?

How many pre-molars does the full set have?

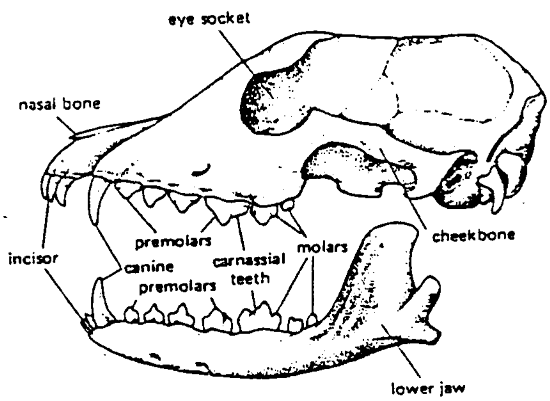
How many molars does the full set have?

How many teeth altogether does the full set have?

Activity 2

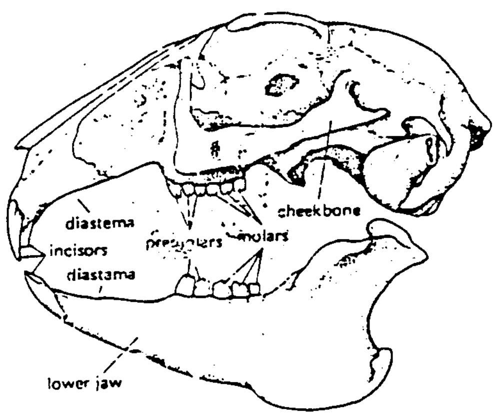
Write dental formulae for the following.

Dog



Skull of a dog showing teeth X0.5

Rabbit



Skull of a rabbit showing teeth X 1
After R. H. Stone and A. B. Cozens, New Biology for West African Schools, Longman Group Ltd.

Using the types of teeth in these skulls to guide you, suggest the diet for a dog and a rabbit.

Suggest the reasons for your answers above.

Lesson 10 - Tooth Structure.

At end of the lesson, pupils should be able to:

1. Identify and describe parts of the tooth.
2. Discuss the care for the teeth.
3. Discuss some dental diseases.

Activity 1 - Tooth decay and its cause

1. Label three test-tubes A - C.

Into test-tube

A. pour enough dilute hydrochloric acid to cover a tooth.

B. Pour enough water to cover a tooth.
C. Put enough saliva to cover a tooth (Rinse the mouth thoroughly with water before collecting the saliva).

2. Extract three teeth from a mammal (e.g. a goat) and poke them in the crown with a sharp instrument - a needle or a forceps.

   How would you describe the hardness of the crown?

3. Place one tooth in each of the three test-tubes, cover the test-tubes with rubber stoppers and leave them in a safe place for two or three days.

4. Wash the teeth and examine them. Using the sharp instrument again, poke the crowns of the teeth.

Compare the teeth from test-tubes A-C with a tooth that is still in the jaw.

Tooth	Observation after two/three days
1. Acid	
2. Water	
3. Saliva	

What happens when you poke the teeth with a forceps?

Tooth	Observation	Interpretation
1. Acid		
2. Water		
3. Saliva		

Which of the teeth in the saliva, acid and water is softer than the tooth on the jaw?

Explain what might have happened in order for this tooth to be softer than the one in the jaw.

What part of the tooth has become exposed in test-tube?

How would you describe the hardness of the top layer of the tooth as compared to the one exposed?

Describe how tooth decay occurs.

The diagram below shows the parts of the tooth including the parts you have just investigated.

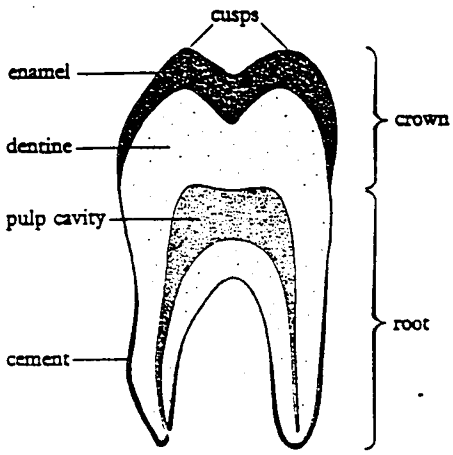


Fig. 9.6 Vertical section of a human molar tooth.

Suggest the functions of any two parts of the tooth.

Activity 2 - Care of the teeth.

We need to take care of our teeth. If a tooth is lost from a permanent set of teeth, no new tooth will grow to replace it.. At least four things can be done to ensure that teeth are kept healthy.

1. Proper and correct use of teeth.

   (a) Suggest things that teeth should not be used for?

2. Cleaniness

   (a) How often should the teeth be brushed?

(b) What can be used to clean teeth.

(c) At cattle posts and lands where there are no shops, what may be used to clean the teeth?

3. Proper diet.

(a) What substances in the diet will help you to develop strong teeth?

(b) Which sorts of food should be avoided in between meals?

Why?

4. Routine check up.
Who should check your teeth at least once a year?

Why?

Lesson 11 - The human alimentary canal.

At the end of the lesson, pupils should be able to:

1. Identify and describe parts of the alimentary canal.
2. Identify organs associated with digestion.
3. Anotate a diagram of the human alimentary canal.
4. Trace the path followed by food from the mouth to the anus.

Activity One

1. Observe the alimenary canal of the dissected rat provided.
2. (a) Look inside the mouth,
   - (i) What types of teeth are present?
   - (ii) Write the dental formula for the rat.

   (b) (i) Locate the oesophagus
   - (ii) Locate the trachea
   - (iii) Suggest a way in which the trachea differs with oesophogus
   - (iv) Suggest the function of the oesophogus
   - (v) Is there a separate oesophogus for food and for water?
   - (vi) Sometimes when you drink water, it chokes you and hence you may cough a lot. There is a belief that this happens because water has gone down the oesophogus sued for food and not for water. Do you agree? Support your answer.

   (c) How would you describe the shape of the stomach?

2. What other parts of the alimentary canal do you notice?
   - (ii) Describe the appearance of these parts.

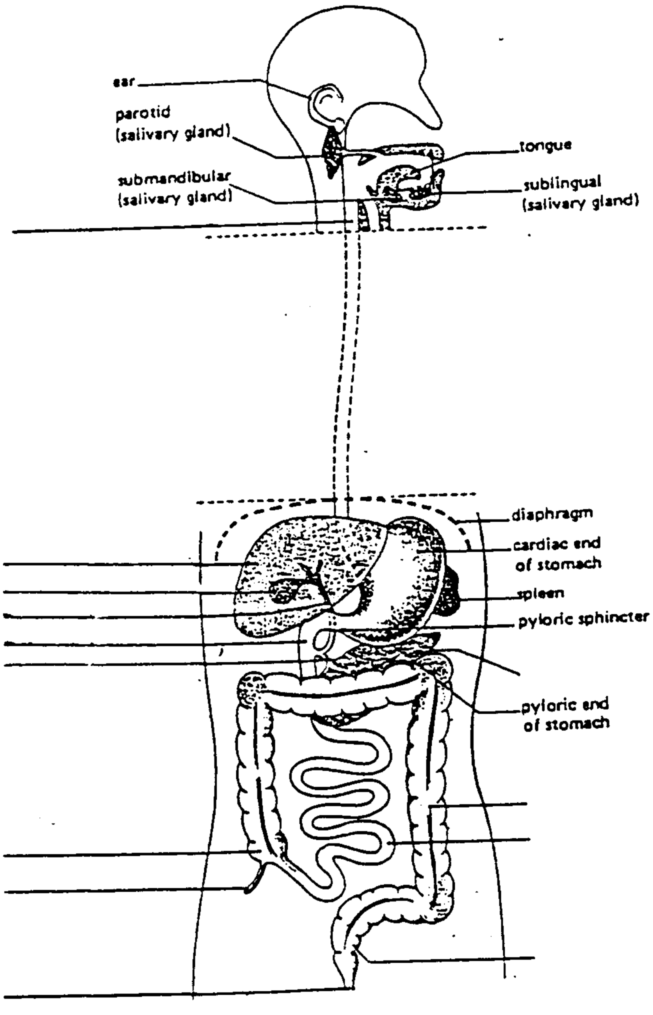
3. Do you notice any parts organs that are not part of the alimentary canal but which help the functioning of the alimentary canal?

   (i) Name any such organs.

Activity 2

The human alimentary canal has got parts corresponding to those of a rat. Differences, however, exist on the emphasis i.e. the calcum for instance is large in the rat and small in men. The appendix too is large in the rat and small in man.

Identify and label the parts of the human alimentary canal on the diagram below.



Lesson 12 - Digestion (In the mouth).

At the end of the lesson, pupils should be able to:

(i) Distinguish between mechanical (e.g. chewing) and chemical (e.g. breaking down starch to glucose) digestion.

(ii) Describe the process of mechanical digestion in the mouth.

(iii) Predict the presence or absence of glucose in experiment where saliva has been boiled or acidifyied.

Carbohydrates, proteins and fats are large food molecules that need to be broken down into smaller units that the body can absorb. This process is called digestion.

Activity 1

1. Place a small piece of bread into your mouth and chew it thoroughly - Do not swallow it.

   (a) What does the teeth do to the piece of bread as you chew it?

This is called mechanical digestion. A piece of bread has been ______________ into ________________ pieces of bread.

During the process of chewing, bread is mixed with ______________.

Describe the taste after the chewed bread has been left on the tongue for sometime.

Is this the same taste it had when you first placed the piece of bread in the mouth?

Suggest a possible explanation of how this taste came about.

Suggest the role of saliva in the process of digestion.
1.

2.

What could happen to the digestion starch if or some reason, saliva could not be secreted into the mouth.

Activity 2

1. Prepare (a) water bath and maintain the temperature at 37°C.

2. Wash out your buccal cavity thoroughly with water and then suck a clean small stone or rubber band to stimulate secretion of saliva. Collect the saliva in a small beaker. Once enough saliva has been collected, pour it into a test-tube and place it in the water bath.

3. (a) Label three test-tubes A,B,C.

   (b) Add $1cm^3$ of solution X to tubes A and B.

   (c) Add $1cm^3$ of distilled water to test-tubes A, B and C.

4. Prepare a spotting tray or white tile with three rows of iodine solution drops.

5. Record the time, then add $1cm^3$ of the warmed saliva (from the water bath) to tube A. Stir the contents with a clean glass rod.

Immediately remove one drop of the mixture, by means of the glassed, and add it to the first drop of iodine solution. Record the colour of the iodine solution. Wash the end of the glass rod.

6. After 3minutes, remove the second drop and put it into the second drop of iodine solution. Record the colour. Rinse the rod. Repeat the test every 3 minutes until the colour of iodine solution no longer changes.

7. Repeat the process for test-tube B over the same length of time BUT do not add saliva to test-tube B. Record the results.

8. Add 1cm^3 of saliva to tube C and repeat the process for test-tube C. Record your results.

9. Now, test the contents of tubes A, B and C for reducing sugar using Benedict's solution.

Record your results.

	Colour of iodine solution from test-tubes		
Time	A	B	C
O			
3 mins			
6 mins			
9 mins			

What does the fact that after sometime iodine does not change colour suggest to you.

What is solution X most likely to be?

Why?

What happened to starch in test-tube A?

How would you show that this is true?

What control experiment would confirm your conclusion?

In about a paragraph, describe what happens to a piece of bread from the time it is placed into the mouth to the time it is swallowed?

Lesson 13 - DIGESTION (stomach)

At the end of the lesson, pupils should be able to:
i) identify the food-stuff digested in the stomach
ii) explain why the digestion of carbohydrates stops in the stomach.
iii) relate peristaltic movements of the stomach to physical digestion.

We have already seen the effect of ptyalin on starch. This effect, however, is affected by several factors. In this experiment we shall explore the factors that affect the activity of ptyalin - and establish whether it acts in the stomach.

<u>Activity 1</u>

1. Rinse your buccal cavity well with water
2. Collect 1/2 test-tube of saliva - such a clean stone or rubber band to increase the flow of saliva. Keep in a water bath at 37 °C.
3. Label three test-tubes 1 - 3.
4. Into each add 1/4 test-tube of starch solution.
5. Divide the saliva into three equal portions of about 1/8 test-tube each.
6. Heat one portion in a boiling water bath for 15 minutes.
7. Add 1 cm^3 of dilute hydrochloric acid to next portion and let it stand for 15 minutes.
8. Add a) acidified saliva to test-tube 1
   b) boiled saliva to test-tube 2
   c) normal saliva to test-tube 3.
9. Leave the test-tubes to stand for at least 10 minutes.

While waiting, predict the results of this experiment when you test with iodine solution and Benedict's' solution.

Predicted Result

Test tube	Iodine	Benedict	Reason
1			
2			
3			

10. Test the contents of test-tube 1-3 for starch and glucose and Record your results.

Results

Test-tube	Iodine Solution	Benedict's Solution	Explanation
1			
2			
3			

What conclusions can be made about the effect of boiling and acidifying saliva on the digestion of starch?

Activity 2

1. Read the following questions carefully before watching the video.

a) Which process pushes the food into the stomach?

b) Describe this process.

c) Which acid is contained in the juice produced by the walls of the stomach

d) Do you expect the enzyme in the saliva to continue to digest starch to glucose in the stomach?

Why?

Describe the experiment that you could use to support your answer.

e) Which food staff is digested in the stomach?

In the stomach, _______________ is digested by the enzyme _________________ to _______________.

This enzyme is produced in the inactive form called __________________________.

Why should this enzyme be produced in an inactive form ?

Lesson 14 - DIGESTION (Small intestines)

At the end of the lesson, pupils should be able to:

1. Relate the liver and the pancreas to digestion.
2. State the enzymes involved in digestion in the ileum and duodenum.

Food is stored in the stomach for sometime before it is passed on to the small intestine. At the time when food is passed on from the stomach, only two foodstuffs would have been digested.______________would have been digested to ____________ by the enzyme in the saliva and _______________would have been digested by____________ in the stomach.

Activity 1 - How far has digestion of food materials gone?

Consider what you have learnt about digestion so far. That is, digestion in the mouth and in the stomach.

a) i. Has digestion of starch occured?

ii. Where was starch digested if it has been?

iii. What was the product when starch was digested if any?

iv. Did any starch remain undigested?

v. Why did it remain undigested if it did?

b) i. Has fats been digested?

ii. Where was fat digested if it has been?

iii. What was the product of the digestion of fats if any?

iv. Did any fat remain undigested?

v. Why did it remain undigested if it did?

c) i. Has proteins been digested?

ii. Where were proteins digested if they have been?

iii. What was the product of the digestion of proteins if any?

iv. Did any proteins remain undigested?

v. Why do you think they remained undigested if they did?

<u>Activity 2</u> - "The advertiser"

The duodenum is looking for two products it could use to aid in the digestion of proteins, carbohydrates and fats.

a) You are the liver and you produce one of these products. Advertise yourself to the doudenum. In doing that,
   i. Describe your product.
   ii. Describe how you store it.
   iii. Say what it can do.
   iv. Say how you think it is suitable for Doudenum wants to do.

b) You are the liver and you produce one of these products. Advertise yourself to the doudenum. In doing that,
   i. Describe your product.
   ii. Describe how you store it.
   iii. Say what it can do.
   iv. Say how you think it is suitable for Doudenum wants to do.

Write your work on the A4 or the Manila paper your teacher provided. Display your work on the wall and copy it to your note book during study time. Look at other pupils' work displayed on the wall.

LESSON 15 - Absorption

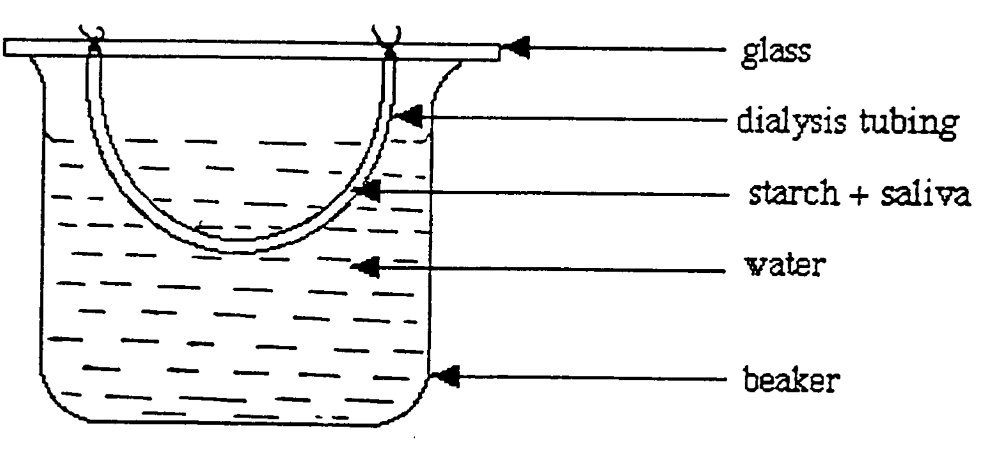
At the end of the lesson, pupils should be able to :

1. state the end products of the digestion of fats, proteins and carbohydrates.
2. describe the structure of the villus.
3. explain how the villus is adapted for absorption of the end products of digestion.
4. discuss the fate of the end products of digestion.

Food materials need to be digested in order to make them small and soluble so that they can be absorbed into the body.

Activity 1

1. Cut a 20cm strip of dialysis membrane. Soak it in a beaker of water to soften it.
2. Collect 2ml of saliva, dilute it to 10ml by adding 8ml of distilled water.
3. Tie a knot at one end of the dialysis membrane and put 10ml of starch solution into the dialysis membrane.
4. Add 5ml of dilute saliva and tie the open end of the dialysis membrane, and rinse it with water.
5. Tie the two ends of the dialysis tubing to a glass rod and place into a beaker of water as shown below :



6. Test the water in the beaker for starch and glucose immediately. Leave for 15 minutes. While waiting, test the starch solution and the remaining saliva for glucose.

7. After 15 minutes test the water in the beaker for the presence of starch and glucose.

What do the results show?

Which nutrients are present?

Where did they come from?

Which nutrients could pass through the membrane?

In this experiment, what would represent the small intestines?

Once the fats, carbohydrates and proteins have been digested, the end products of this digestion need to reach the body cells where they are needed. Absorption, is a process that moves these foodstuffs from the small intestine to the blood stream. The small intestine is adapted for absorption.

Activity 2 - structure of the small intestine

Carefully study slide number 5 on bio strip M17. It shows the longitudinal section of the small intestine.

How would you describe the inner lining of the small intestine?

How does the structure of the small intestine make it more suitable for digestion?

Suggest would happen to glucose, amino - acids, fatty acids and glycerol after absorption.

a) Glucose -

b) Amino - acids -

c) Fatty acids and glycerol -

APPENDIX H

Biology Laboratory Interactions Observation Schedule(BLIOS).

Categories.	Tallies
Teacher.	
1. Empathises	
2. Gives verbal reward	
3. Accepts and reinforces students' response.	
4. Ignores student's response.	
5. Challenges student's response.	
6. lectures.	
7. Questions: QF,QR,QL,QP	
8. Responds to question.	
9. Directs	
10. Supervises/ individual attention.	
11. Manipulates apparatus.	
12. Rebukes, criticises, exerts authority.	
Student.	
13. Responds to question	
14. Questions	
15. Initiates talk	
16. Experiments	
17. Reads, writes and /or draws.	
18. Non - productive activities.	

Presentation of the lesson.

Evidence of plannig before the lesson.	1	2	3	4	5
Presentation of subject content.					
Logical lesson presentation.(lesson objectives stated, clarity, smooth transition through the lesson)	1	2	3	4	5
Appropriate use of questions.(using questions to elicit students' ideas, to stimulate thinking, to direct thinking and discussions, answerability, relevance).	1	2	3	4	5
Encouragement of personal construct-ion of knowledge.(use of analogies, exemplars,illustrations to aid comprehension, eliciting contradictions, inconsistencies, and descrepancies in the students' responses.)	1	2	3	4	5
Mastery of the subject matter. (versatile with content matter,ability to present concepts in a variety of contexts,ability to elicit and develop students ideas, ability to identify incipient problems and help students overcome them.)	1	2	3	4	5
Preparation and use of appropriate teaching materials.(availability and use of teaching materials, using large enough materials for all to see, effective use of equipment, charts, audio visuals etc.)	1	2	3	4	5
Use of chalkboard.(legible writing, dividing up the chalkboard into appropriate sections, writing systematically across the board, using duster to clean the board)	1	2	3	4	5
Appropriate use of teaching techniques (ability to change teaching techniques as the classroom environment dictates, ability to pre-empt learning problems and change teaching style to address them without disrupting the lesson)	1	2	3	4	5
Evaluation of lesson objectives. (relevance, adequacy, appropriateness of timing).	1	2	3	4	5

Class management.

Efficiency. (gets class settled and ready, efficient distribution of apparatus, has all necessary things at the right places)	1	2	3	4	5
Order and control. (handles noise and disturbances effectively, is fair to all students, consistent and respectful in the way he handles problems and cases of indiscipline)	1	2	3	4	5

Class interactions.

Student participation. (enhanced opportunities for students to manipulate apparatus, encourages students to participate)	1	2	3	4	5
Pleasant learning environment. (freedom to ask questions, suggest ways of approaching tasks, pace the work, choose partner)	1	2	3	4	5
Small group discussions. (encourages discussions in small groups, discussions on contextual issues related to the lesson.)	1	2	3	4	5

Personal traits.

Sensitivity to individual differences of students. (effects of age, sex, culture, ethnic groups, cognitive ability, family background on students' participation and achievement.)	1	2	3	4	5
Communication skills. (purism, diction, inflection and avoidance of distructive mannerisms)	1	2	3	4	5
Self presentation. (poise, confidence, appearance)	1	2	3	4	5

APPENDIX I

Age:

Sex:

Form:

Date:

Code: PRC. [ ], PRT. [ ],
POC1.[ ], POC2.[ ]
POT. [ ].

Biology Achievement Test (BAT)

Animal Nutrition.

Answer all the questions on the question paper. To show the correct response, circle the letter that corresponds to your best choice.

1. Which of the following pairs of food types are rich sources of protein?

   a) Mophane caterpillar and lean meat.
   b) Potatoes and onions
   c) Egg albumen and mealie-meal
   d) Soya beans and mealie-meal

2. One family was known to have tea and bread at breakfast, mealie-meal and beef for lunch and tea and fat cakes for supper every day. The children soon became sick and developed bleeding gums.

   What could they be suffering from?

   a) Marasmus
   b) Scurvy
   c) Kwashiorkor
   d) Common cold

   Explain your answer.

3. Which of the following is most likely to provide a balanced diet?

   a) Mealie-meal
   b) Rice
   c) Milk
   d) Meat

Explain your answer.

4. Which of the following pairs of food types is the richest source of carbohydrates?

   a) egg yolk and Mophane caterpillar
   b) mealie meal and rice
   c) lean meat and oranges
   d) cheese and brown bread

5. Carbohydrates

   a) repair and replace worn out tissues
   b) protect our bodies against diseases
   c) transmit impulses through the nerves
   d) provide the body with energy

6. What would you advise someone who as a result of a poor diet suffers constipation to do ?

   a) eat food rich in proteins
   b) increase intake of food rich in fibre
   c) eat food rich in carbohydrates
   d) increase intake of food rich in minerals

   Explain your answer.

7. Beans and eggs fed to children will help them develop strong bones because they provide:

   a) vitamin A and proteins
   b) vitamin B_1 and iron
   c) fluorine and chlorine
   d) phosphorus and calcium

8. Tumelo could not see very well at night . His friend Aobakwe advised him to eat a lot of mangoes, egg yolk, paw-paws, and liver. Tumelo did this and his eye sight at night became good again. This could suggest that these food types are rich sources of:

a) proteins
b) iron
c) vitamin E
d) vitamin A

Explain your answer.

9. Which of the following diets is likely to help a person suffering from Kwashiorkor to recover ?

a) samp with beans and Mophane caterpillar
b) mealie-meal and spinach
c) pumpkins, rice and tomato sauce
d) sorghum meal and cabbage

Explain your answer.

10. A long beak on the humming bird and a proboscis on the mosquito are examples of an adaptation for

a) feeding on fluid food
b) feeding on solid food
c) biting and fighting
d) pecking and biting.

11. Ptyalin digests starch in the mouth. When the food is swallowed and passed to the stomach, digestion of starch by ptyalin stops. This happens because:

a) all starch would have been digested in the mouth
b) another enzyme will digest starch in the stomach
c) the stomach is too acidic for ptyalin to act
d) the stomach is too alkaline for ptyalin to act.

12. What might happen if the bile duct is blocked preventing the flow of bile into the small intestines ?

a) fats will be digested to fatty acids
b) proteins will not be digested
c) fats will not be digested
d) carbohydrates will not be digested

Explain your answer.

13. What might happen if the walls of the stomach fail to produce hydrochloric acid can be that:

a) both starch and proteins will be digested in the stomach
b) digestion of starch will continue normally in the stomach
c) Proteins in the stomach will be digested normally
d) There will be constipation

Explain your answer.

14. How would you show that lean meat contain some proteins?

a) crush a small amount of lean meat in about $5cm^3$ of water, add Benedict's solution and heat in a water bath.
b) add $1cm^3$ of dilute sodium hydroxide, then $1cm^3$ of dilute copper sulphate and heat in a water bath.
c) add $1cm^3$ of dilute sodium hydroxide, then $1cm^3$ of dilute copper sulphate.
d) add $1cm^3$ of dilute copper sulphate, then $1cm^3$ of dilute sodium hydroxide.

15. Khumo finds a skull in the bush near her home. Among the teeth still remaining on this skull are two large canines on the lower jaw. This skull must be from an animal that fed mainly on:

a) nuts and hard fruits
b) flesh
c) grass
d) fresh fruits and vegetables

16. An animal with a dental formula $I^0/_3$ $C^O/_0$ $P^3/_3$ $M^3/_3$ is most likely to be a:

a) predator
b) carnivore
c) herbivore
d) omnivore

Explain your answer.

17. A dental formula for a person with 32 teeth; 8 incisors, 4 canines, 8 premolars and 12 molars can be expressed as:

a) $I^2/_2$ $C^1/_1$ $P^2/_2$ $M^3/_3$
b) $I^1/_3$ $C^0/_2$ $P^1/_3$ $M^2/_4$
c) $I^3/_1$ $C^2/_0$ $P^3/_1$ $M^4/_2$
d) $I^3/_3$ $C^0/_0$ $P^1/_1$ $M^4/_4$

Explain your answer.

18. Which one of the following is not true about proteins?

a) they are destroyed by heat
b) urea is formed out of excess proteins
c) they can be used to provide energy
d) they can be stored in the body as amino-acids.

19. Flies might spread diseases easily to people who do not cover their food. The major reason for this could be that

a) they suffer the same diseases with man and can spread these through the air.
b) they spit the digestive juices on the food before sucking the food up, thus contaminating the food.
c) as the houseflies sit on the food, they lay eggs which may hatch into worms that would cause disease.
d) they fall into the food and die causing the food to be contaminated.

20. After thoroughly rinsing her mouth with water, Bame collected some saliva into a test-tube. She then added this saliva to a test-tube containing 2% starch solution. She allowed the solution to stand for 15 minutes and tested the solution with Benedict's solution. She realised that glucose is present. She concludes that starch has been digested to glucose. Julia disagrees saying that glucose could have been in the mixture right from the beginning.

How could Bame show Julia that no starch was present in the mixture?

a) rinsed her mouth more thoroughly while Julia is watching.
b) tested the starch solution only for the presence of glucose before the adding saliva.
c) tested the saliva only for the presence of glucose before adding it to starch.
d) tested the mixture for the presence of glucose immediately after mixing.

21. Moemedi collected some saliva too after thoroughly rinsing his mouth. He then added some acetic acid to the starch to make it acidic and then added saliva. He allowed the mixture to stand for 15 minutes and then tested it for the presence of glucose.

Predict the results of this experiment.

a) glucose will be present because the enzyme in the saliva will digest starch to glucose.
b) glucose will be present because acetic acid will digest starch to glucose.
c) glucose will not be present because the mixture is alkaline.
d) glucose will not be present because the mixture is acidic.

In an experiment to show the effect of saliva on the digestion of starch, a water bath was prepared and test-tubes 1-3 were set up.

Test-tube 1 contained $1cm^3$, of 2% starch, $1cm^3$ distilled water and $1cm^3$ saliva.
Test-tube 2 contained $1cm^3$ of 2% starch and $1cm^3$ of distilled water.
Test-tube 3 contained $1cm^3$ saliva and $1cm^3$ distilled water.

22. Predict the result from test-tube 3 after being left standing for 10 minutes and then tested with both iodine solution and Benedict's solution.

a) Iodine solution will turn blue-black and Benedict's solution will turn orange.
b) Benedict's solution will turn orange because saliva would digest starch to glucose.
c) Both iodine and Benedict's solutions will not change colour.
d) Iodine will not change colour but Benedict's solution will turn orange.

Give a reason for your answer.

23. What is the purpose of test-tube 2?

a) to show that distilled water has no effect on starch.
b) to show that starch has no effect on distilled water.
c) to show that saliva has no effect on distilled water.
d) to show that glucose is produced when distilled water acts on starch.

24. Farmers in Digawana realised that after the good rains this tear, the number of rabbits increased greatly. This is probably because

a) There is a lot of food to eat.
b) They might have been carried by water from other areas to Digawana.
c) Farmers in other areas shoot and hunt them with dogs, so they moved to Digawana.
d) People in Digawana do not make a lot of noise that scares the rabbits away.

Karabo noticed three different animals in the little forest a kilometre away from his home. He passed this forest four times in a week. Each time he counted the number of animals he referred to as A, B and C. This is what he recorded.

Animal	First time	Second time	Fourth time	Fifth time
A	20	18	22	20
B	3	3	0	4
C	12	8	6	14

If these numbers are representative of the actual numbers of these animals in this environment,

25. Animal B is most likely to be physically larger than A and C.

T	F

26. Animal C is most likely feeding on animal A.

T	F

APPENDIX J

STUDENT PARTICIPATION INVENTORY (SPI).

Age: Code:PRC. [ ], PRT. [ ]

Sex: POC1.[ ], POC2.[ ]

Date: POT. [ ]

The following statements describe activities that are likely to take place in your class. Please honestly indicate the extent to which these take place in your class by circling your best choice.

5 = always, 4 = frequently, 3 = sometimes, 2 = rarely, 1 = never

When the lesson starts, our teacher usually:

1.	Talks for a long time while we are listening silently.	1	2	3	4	5
2.	tells us what we should be able to do in a lesson.	1	2	3	4	5
3.	asks us questions that require us to recall facts from the previous lesson.	1	2	3	4	5
4.	asks us questions that challenge us to think about what we are going to do.	1	2	3	4	5
5.	allows us to raise and discuss issues related to the topic.	1	2	3	4	5
6.	allows us to discuss some of our experiences at home which relate to the topic.	1	2	3	4	5

During whole class discussions:

7.	everyone in the class is encouraged to talk.	1	2	3	4	5
8.	only the bright students get a chance to say their ideas.	1	2	3	4	5
9.	I never get a chance to talk.	1	2	3	4	5
10.	I do not want to talk because if I make a mistake others will laugh at me.	1	2	3	4	5
11.	I participate in the discussion because everyone is free to talk.	1	2	3	4	5
12.	boys get more chances to talk than girls	1	2	3	4	5
13.	only those who are good in English do a lot of talking.	1	2	3	4	5
14.	some students sleep during the biology class.	1	2	3	4	5

In small group discussions:

15.	the bright students talk most of the time.	1	2	3	4	5
16.	everyone gets a good chance to talk.	1	2	3	4	5
17.	boys talk most of the time.	1	2	3	4	5
18.	we learn a lot from each other.	1	2	3	4	5
19.	we argue a lot and never agree on anything.	1	2	3	4	5
20.	boys lead the discussion while girls record					

the points agreed on.	1	2	3	4	5
21. we help each other understand the task assigned to us.	1	2	3	4	5
22. we are given enough time to solve problems raised in our groups.	1	2	3	4	5

During a demonstration:

23. the teacher makes sure that we all can see.	1	2	3	4	5
24. some students climb on top of stools and tables in order to see well.	1	2	3	4	5
25. we ask questions when we do not understand.	1	2	3	4	5
26. the teacher tells us the purpose of the demonstration.	1	2	3	4	5
27. only boys help the teacher perform the demonstration.	1	2	3	4	5
28. no pupil is ever asked to help the teacher to do the demonstration.	1	2	3	4	5
29. some students are asked to perform the demonstration to the class.	1	2	3	4	5
30. only the big students help the teacher during a demonstration.	1	2	3	4	5
31. the teacher requires us to explain why we carry out certain steps in the demonstration.	1	2	3	4	5
32. the teacher tells us why he carries out every step of the experiment.	1	2	3	4	5

During small group practical work:

33. we decide the experiments we want to do.	1	2	3	4	5
34. I get a chance to handle and use apparatus to do the experiments.	1	2	3	4	5
35. some students never handle the apparatus and do the experiments.	1	2	3	4	5
36. everyone in our group gets a chance to take part in the experiment.	1	2	3	4	5
37. boys do the experiments while girls record the readings or results.	1	2	3	4	5
38. we discuss the observations and agree on what to record.	1	2	3	4	5
39. brighter students always tell the group what to record.	1	2	3	4	5
40. boys tell the group what should be recorded.	1	2	3	4	5
41. the group is allowed to decide how to carry out some parts of the experiment.	1	2	3	4	5
42. we discuss our results with the class and explain why we think our results are accurate.	1	2	3	4	5
43. at the end of the lesson, the teacher gives us homework.	1	2	3	4	5
44. I try to finish my homework before everyone else in the class.	1	2	3	4	5

45.	we help each other to finish the homework.	1	2	3	4	5
46.	some pupils do not finish their homework.	1	2	3	4	5
47.	teacher checks to see if a homework is done.	1	2	3	4	5
48.	We are allowed to copy each other's solution to an assigned task.	1	2	3	4	5

APPENDIX K

Student Questionnaire (SQ

Sex: Age:

The following statements represent characteristics of an outstanding and exemplary biology teacher. Please indicate your opinion by circling the appropriate choice.

A = Agree, D = Disagree, U = Undecided.

An Exemplary biology teacher should:

1.	not provide girls and weaker students ample opportunities to participate in the lesson because they delay other students.	A	D	U
2.	always decide for the students the groups they will work in during discussions and practical work.	A	D	U
3.	encourage students to memorise what they have been taught for tests and examinations.	A	D	U
4	encourage students to participate actively during the lesson.	A	D	U
5.	provide opportunities for students to do their experiments, and avoid doing the experiments for them.	A	D	U
6.	encourage students to discuss tasks assigned to them in small groups.	A	D	U
7.	make sure that what is taught to the students is related to their experiences at home.	A	D	U
8.	give homework that is related to the work done in the class and make sure that it is marked.	A	D	U
9.	encourage students to plan and carry out the experiments assigned to them.	A	D	U
10.	use practical work to clarify and confirm theoratical work done in the class.	A	D	U
11.	provide adequate and appropriate materials for the lesson.	A	D	U
12.	avoid embarassing students by directing questions to them even when they do not raise their hands to answer.	A	D	U
13.	direct questions to students who are likely to answer them correctly.	A	D	U
14.	not allow students to talk during the lesson			

	except when they are asked to do so by the teacher.	A	D	U
15.	not be too familiar with students.	A	D	U
16.	try to understand things from the point of view of the students.	A	D	U
17.	give verbal rewards (like "good") for correct responses.	A	D	U
18.	not say anything when the student's answer is wrong but call on another student to answer.	A	D	U
19.	create a classroom atmosphere in which students ask questions and make suggestions about classroom activities without feeling threatened.	A	D	U
20.	criticise, rebuke and warn students about the consequences of their behaviours.	A	D	U
21.	make sure students are always doing assigned tasks in the lesson and not playing.	A	D	U
22.	allow students to answer questions in a chorus, so that they get to work like a team.	A	D	U
23.	not display laboratory rules in the laboratory because students know them by heart.	A	D	U
24.	not keep eye contact with the students during the lesson because it makes them shy.	A	D	U
25.	not move around the class because it disturbs the students.	A	D	U
26.	always have instructional materials ready before the lesson.	A	D	U
27.	not waste time cleaning the board, instead he should just find a clean part of the board and start teaching immediately.	A	D	U
28.	write on the board clearly and regularly.	A	D	U
29.	speak very softly so that students listen very carefully.	A	D	U
30.	choose topics that are likely to come out in the examination,teach them well and leave out things that are not likely to come out.	A	D	U
31.	teach students at a pace and manner that ensures that they understand what is taught, even if it means not covering the whole syllabus.	A	D	U
32.	cover the syllabus very fast so that whatever comes out in the examination is at least briefly covered.	A	D	U
33.	use the bright students to determine the rate at which to teach.	A	D	U
34.	use the slow learners to determine the pace of the lesson.	A	D	U

APPENDIX L

TEACHER INTERVIEW SCHEDULE (TIS)

1. Metaphors are sometimes used to describe reality about teaching and learning in classrooms. e.g. "Teaching and learning is like a sponge. The more you pour the more it absorbs" On the other hand teaching and learning may be described as "an adventure", "sowing and reaping", or "selling and buying" etc.

   What metaphor would you use to represent teaching and learning in Biology lessons?

2. Is there in your view a model of teaching that can be described as exemplary ?

   If not, is it just the ideal?

3. If yes, what teaching behaviour can be regarded exemplary?

   How can one recognise an exemplary biology teacher?

4. What constraints if any, may make it difficult to teach in an exemplary fashion?

   i. large classes
   ii. student's cognitive development
   iii. inadequate facilities
   iv. lack of personel to assist teachers
   v. the nature of the curriculum
   vi. the nautre of the examination system.
   vii. language difficulty
   viii. Others (explain)

5. The Biology achievement Test (BAT) was used to evaluate achievement in biology lessons in this study. Do you think it is a suitable instrument in terms of

   i. the students' level of cognitive development?
   ii. aiding conceptual development?
   iii. the level of language used?
   iv. the content examined?

6. Which questions on the BAT do you think students are not likely to answer successfully? Why?

   i. Lack of background knowledge
   ii. Students were not taught that.
   iii. Students are likely to reflect their alternative conceptions.
   iv. The questions are poorly asked.

7. Do you think that the use of exemplary materials enhanced students' participation?

   If yes, What could be the reason for this?

   If no, Why?

8. What did you percieve as your role when using exemplary materials?

i. to facilitate the learning process
ii. to manage the class
iii. to co-learn with the students
iv. to impart knowledge

9. Given the time constraint, the fact that society judges the quality of a teacher by the good results in the national examinations and the need to teach for conceptual change in biology lessons, which of the following is an exemplary biology teacher likely to do?

i. concentrate on topics that are likely to come out in the examination and teach them well, leaving out things that are not so likely to come out.
ii. teach the content at a pace and manner that ensures meaningful learning even when that could mean not finishing the syllabus at the end of the year.
iii. go through the syllabus at a pace that will ensure that everything in the syllabus is at least briefly covered.
iv. teach concepts and skills of immediate application to the world of work.
v. teach topics relevant to the learners' daily experiences.
vi. strive for conceptual understanding other than coverage of content.
vii. provide prototype illustrations and essential concepts and ideas rather than cover the syllabus.
ix. Others (suggest)

10. i. What is your overall view about exemplary teaching?

ii Given the time constraints, large classes and scarcity of facilities would you use and exemplary teaching approach?

iii. What in your view are the merits and demerits of exemplery teaching?

iv. If science in general and biology in particular, is a form of inquiry, would you consider exemplary teaching a practical and realistic approach to teaching by inquiry?

APPENDIX M

STUDENT INTERVIEW SCHEDULE (SIS).

1. You have written the Biology Achievement Test. What do you think about it?
   - i. Was it easy, and do you think you have done well in it?
   - ii. Did the test help you to remember the things you have been taught?
   - iii. Did it require you to think and reason a lot?
   - iv. Was the test written in difficult English and so difficult to understand?
   - v. Was it clear to you what the questions were all about?

2. We are now going to consider a few questions, each at a time.
   - i. Look at question (No.), do you still think your response is correct?
   - ii. Explain why you think this is the correct response.
   - iii. Consider one of the alternatives you did not choose. Explain why you think it is not correct.

3. During a biology practical, what do you prefer to do?
   - i. Read the instructions for the group.
   - ii. Manipulate apparatus doing the experiment.
   - iii. Make observations and tell the group.
   - iv. Record the results.
   - v. Manage the group.
   - vi. Others (specify)

4. Did using the learning materials help you learn Biology better?

If no, why?

- i. it made learning science difficult.
- ii. instructions were not clear and were hard to follow.
- iii. contributed to your being bored and tired in the lessons.
- iv. the activities to be carried out were too many.

If yes, how?

e.g. Did it

- i. help to arouse your interest in biology?
- ii. help you remember what you learnt much longer than if you had not done practical work?
- iii. help you to understand the theory better?
- iv. motivated you to study biology?
- v. help you to use scientific apparatus better?
- vi. help you to be creative in biology?
- vii. help you to work like a real scientist?
- ix. help to improve your accuracy in observation, measuring etc.

5. How do you rate your level of participation?
   i. very high ii. high iii. not sure iv. low v. very low.

6. State briefly what you gained in your study of nutrition.

APPENDIX N

PUPILS' CLASS ENVIRONMENT INVENTORY.

ACTUAL

The following statements may describe your classroom environment. Please indicate what your **actual** classroom environment is like by circling the correct response opposite the statement that best describes it.

This is not a test. Please answer **all** the questions as honestly as you can.

School__________________ Code____ Sex_____ Age_____yrs.

	Please remember that you are describing how your **actual** classroom is.	circle your answer.	For official use
1.	Pupils in my class like fighting a lot.	Yes No	____ I
2.	We learn a lot in our biology lessons.	Yes No	____
3.	Biology is a difficult subject.	Yes No	____ I
4.	Pupils in my class do not like discussing with others.	Yes No	____ I
5.	Pupils in my class are friendly.	Yes No	____
6.	Pupils in my class steal each others'things.	Yes No	____ I
7.	Other pupils do not like my biology class.	Yes No	____ I
8.	Experiments in biology are long and difficult.	Yes No	____ I
9.	Pupils in my class always struggle to get the best marks.	Yes No	____
10.	Pupils in my class study biology together.	Yes No	____
11.	Pupils in my class always take other pupils' books.	Yes No	____ I
12.	Biology is useful in our lives.	Yes No	____
13.	I hardly ever finish my biology assignments because they are always difficult.	Yes No	____ I
14.	We are happy when we all do well in the classwork tasks and assignments.	Yes No	____
15.	We help each other to finish tasks in biology lessons.	Yes No	____
16.	I have many friends in my class.	Yes No	____
17.	We always work hard and finish our practical work in time during biology lessons.	Yes No	____
18.	Only a few students are doing well in biology.	Yes No	____ I
19.	Pupils in my class always hide their work away from each other during biology lessons.	Yes No	____ I
20.	Pupils in my class are not friendly to me.	Yes No	____
21.	Pupils in my class fight for stools in biology lessons.	Yes No	____ I
22.	We do not like our biology lessons.	Yes No	____ I

23.	The apparatus used in biology lessons are difficult to use.	Yes No	____	I
24.	We often compete to finish our assignments first.	Yes No	____	
25.	Pupils in my class like working together in small groups and helping each other to understand biology.	Yes No	____	
26.	Students in my class always rush for apparatus.	Yes No	____	I
27.	Pupils in my class are always happy during the biology lessons.	Yes No	____	
28.	Drawing biology specimens is difficult.	Yes No	____	I
29.	Some pupils in my class do not tell someone when he or she writes wrong answers.	Yes No	____	I
30.	During biology lessons, we allow each other to take part in carrying out the practical work.	Yes No	____	
31.	The bigs words used by the teacher makes me hate the subject.	Yes No	____	

APPENDIX O

PUPILS' CLASS ENVIRONMENT INVENTORY.

PREFERRED.

The following statements may describe your classroom environment. Please indicate what your **preferred** classroom environment would be like by circling the correct response opposite the statement that best describes it.

This is not a test. Please answer all the questions as honestly as you can.

School____________________ Code_____ Sex______ Age______yrs.

Please remember that you are now describing how you **would like or prefer** your classroom to be like.		For official use
1. I would not like pupils in my class to fight each other.	Yes No	____ I
2. There is much more to learn in our biology class.	Yes No	____
3. Biology should not be as difficult a subject as it is now.	Yes No	____
4. Pupils in my biology class should try to discuss with each other.	Yes No	____
5. I wish pupils in my class were a bit more friendly.	Yes No	____
6. Pupils in my class should not be stealing each others' things.	Yes No	____
7. Pupils in my class should show more interest in the subject.	Yes No	____
8. Experiments in biology should not be as long and difficult as they are now.	Yes No	____
9. Pupils in my class should not always struggle to get the best marks.	Yes No	____ I
10. Pupils in my biology class should try to study biology together rather than compete with each other.	Yes No	____
11. Pupils in my class should stop taking other pupils' biology books and apparatus.	Yes No	____
12. Biology would be useful for us in the future.	Yes No	____
13. I wish the number of my biology assignments were greatly reduced.	Yes No	____
14. We would be happier if we all do well in the classwork and assignments in biology.	Yes No	____
15. We should help each other to finish tasks and assignments in biology lessons.	Yes No	____
16. I would like to have more friends in my biology class.	Yes No	____

17. We should always work hard and finish our biology practical work in time during biology lessons. Yes No ____
18. Not only a few students should do well in biology. Yes No ____
19. Pupils in my class should not always hide their work away from each other. Yes No ____
20. Pupils in my biology class should be more friendly to me. Yes No ____

21. All pupils in my biology class should have stoolsto sit upon. Yes No ____
22. We should show more interest in our biology lessons. Yes No ____
23. The apparatus used in biology lessons should not be difficult to use. Yes No ____
24. We should not rush to complete first our assignments in biology. Yes No ____ I
25. Pupils in my biology class should work together in small groups and help each other to understand biology. Yes No ____

26. Students in my class should not always rush for biology apparatus. Yes No ____
27. I want ot see pupils in my biology class happier than they are now. Yes No ____
28. Drawing biology specimens should not be as difficult as it is now. Yes No ____
29. Pupils in my biology class should tell eacg other when wrong answers are given or written down. Yes No ____
30. During biology lessons, we should allow each other to take part in carrying out the practical work. Yes No ____
31. The biology teacher should not use big words such that it makes me hate the subject. Yes No ____
32. If the biology lessons are made more interesting and enjoyable some of us may one day become

    a) medical or veterinary doctors. Yes No ____
    b) nurses. Yes No ____
    c) agriculturists Yes No ____
    d) biology teachers. Yes No ____