FACTORS INFLUENCING THE IMPLEMENTATION OF THE PROCESS APPROACH IN BIOLOGY SECONDARY EDUCATION

by

THELMA DE JAGER

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PROMOTER: PROF J G FERREIRA

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DECLARATION

Student number: 662-791-9

I declare that **FACTORS INFLUENCING THE IMPLEMENTATION OF THE PROCESS APPROACH IN BIOLOGY SECONDARY EDUCATION** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

(Mrs T. de Jager)

18|03|02

Date

SUMMARY

FACTORS INFLUENCING THE IMPLEMENTATION OF THE PROCESS APPROACH IN BIOLOGY SECONDARY EDUCATION

By: T DE JAGER
Degree: DOCTOR EDUCATION IN DIDACTICS
Supervisor: PROF J.G. FERREIRA

South Africa needs an economy which is competitive and successful. Therefore, it is important that an education system will provide a skilled work force. Learners need to develop biology skills that will equip them for life, enable them to solve problems and think critically. Unfortunately South Africa is presently encountering a lack of skilled citizens. The reasons for this most probably is that the biology curriculum is mainly discipline-based, content-loaded and largely irrelevant, resulting in learners not furthering their studies in biology and related fields.

The biology matriculation examination has a strangle hold on what is taught. Lengthy, content-loaded curricula emphasise the memorising of facts by means of expository teaching methods, leaving little opportunity to teach the application of information and skills to solve problems in real life situations. The teaching methods of biology are thus not sufficiently stimulating and motivating. Biology teaching should not only concentrate on facts or explain facts to learners, but should also concentrate on ways or processes by means of which these facts can be obtained.

To implement a process approach where learners can develop basic- and integrated skills is not an easy task for those involved. The empirical research of this study, confirmed the findings throughout the literature study that various factors hamper the effective implementation of the process approach. It is important that negative factors such as 'large classes' and 'a lengthy syllabus' (in historically disadvantaged [HD] and advantaged schools [HA]) and 'lack of equipment' and 'resource material' (only in HD schools) which received high percentages in the survey, will duly be considered when implementing the process approach, *Curriculum 2005* or *21*. These factors can exert a powerful influence on the success of any changes in biology education.

To ensure the successful implementation of the process approach it is important that all teachers receive adequate in-service training to keep abreast with new teaching strategies and methods.

KEY WORDS

Biology, process approach, processes, basic skills, integrated skills, problem-solving, inquiry, critical thinking, outcomes, learner-centred.

DEDICATION

This thesis is dedicated

to

My late father, Joseph Menezes, my mother, Maria Menezes.

my sons

Christiaan and Vincent

and

my husband

Willie

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ORIENTATION TO THIS RESEARCH

1.1 INCENTIVES FOR THIS INVESTIGATION

In 1995 South Africa already had a work force of more than 11 million people, of whom 30 percent have had no education at all; 36 percent have only had primary schooling, and 31 percent have undergone secondary schooling (De Beer 1995:3). Only 3 percent of the total population has had some kind of tertiary education (De Beer 1995:3 and Papenfus 1995:59). The dropout figure after enrolment for the high school Matriculation Certificate (Grade 12) can be as high as 75 percent. The pass rate for this examination was 52,3 percent in 1999 (Strauss, Van der Linde & Plekker 1999:10). From these statistics, the conclusion can be drawn that the education or the examination system, or both, might be ineffective, since significant numbers of the school population perform poorly. In addition, many school-leavers seem ill-equipped to cope with the demands of the job market, thus not contributing to the economic growth of the country (Spargo 1995a:30-34).

In order for South Africa to develop an economy which is competitive and successful, it needs an education system that will provide a skilled work force (Centre for Education Policy Development 1995:4-5 and Department of Education 2000b:3). Learners need to develop skills that will equip them for life, enable them to solve problems and think critically (Curriculum Frameworks for Science and Technology and Mathematics 1995:3 and Kahn 2000:19). Unfortunately, South Africa is currently encountering a lack of skilled citizens (Doidge 1995:31; Niebuhr 1993:6 and Vermaak 1996:*pers. comm.*).

The skills-crisis was underscored by the Foundation for Research Development, which compared South Africa's skilled citizens to those of one of its main trading countries, namely Japan. In Japan there are 71 biologists, scientists and engineers for every 100 people, whereas in South Africa the figure is 3,3 for every 100, and this figure is still dropping every year (Harper 1997:11). The reason for the decrease in numbers, especially in biology, could possibly be ascribed to the current biology curriculum which does not provide for the needs of the individual and the community (Poliah 1996:*pers. comm.* and Vermaak 1996:*pers. comm.*). Hockey (1995:78) and Papenfus (1995:59) claim that the biology curriculum is mainly discipline-based, content-loaded and largely irrelevant, resulting in learners not furthering their studies in biology and related fields after school, even though researchers at the Institute for Education Planning (RIEP) illustrated that 85,16 percent of Black and 83,13 percent of Coloured learners chose biology as a secondary school subject (Strauss, Plekker, Strauss & Van der Linde 1994:10).

In 1996 Strauss, Plekker, Strauss and Van der Linde (1996:13) indicated that 66,53 percent of biology learners passed; this number dropped to 59,81 percent in 1999 (Strauss, *et al.* 1999:12). From these statistics it is evident that despite the high popularity of biology, many learners fail the subject.

According to EduSource Data News (1993:11), of the 50 791 Black learners who wrote the biology examination, only 24 965 passed. Therefore only 49 out of every 100 of these candidates pass, while 98 out of every 100 White biology learners passed. It is important to determine ways to combat this high failure rate of Black learners in order to improve the overall pass rate. De Beer (1995:18); Dekker (1996:*pers. comm.*); Fraser (1996:*pers. comm.*); Ferreira (1996:*pers. comm.*); Papenfus (1995:60); Slabbert (1992:35) and Watson (1990:49), claim that the main problems in the teaching of biology resides in the following:

- A too heavy emphasis on content.

- The syllabus content and the learner's environment are far removed from one another, and often incompatible.

- The teacher's teaching strategies do not motivate the learners or capture their interest.

Vermaak (1996:*pers. comm.*) and Slabbert (2000:*pers. comm.*) elaborate further, by pointing out that the matriculation biology examination has a stranglehold on what is taught. Lengthy content-laden curricula emphasise the memorising of facts by means of expository teaching methods, leaving little opportunity to teach the application of information and the skills to solve problems in real life situations. The teaching methods of biology are thus not sufficiently stimulating and motivating.

De Beer (1995:15) is of the opinion that when teachers engage in practical work, learners are often merely expected to handle the laboratory equipment and to follow simple instructions on worksheets (De Beer 1995:15). Teachers are not using the needed deductive activities to enable learners to develop the necessary problem-solving skills.

Education specialists are of the opinion that covering only content (*the product*) is still the biology teacher's highest priority, and not the development of skills (*processes*) which learners need for the acquisition and application of information (Fraser 1996:*pers. comm.*; Niebuhr 1996:*pers. comm.*; Papenfus 1995:60; Van Niekerk 1993:2 and Tobin, Tippins, & Gallard 1994:53-54).

Biology teaching should not only concentrate on facts or explain facts to learners, but should also concentrate on ways or processes by means of which these facts could be obtained. This does not imply that teachers should not teach facts; but should rather teach *fewer facts* and *more processes*.

According to Van Aswegen, Fraser, Nortjè, Slabbert and Kaske (1993:14) effective biology teaching and learning are only possible if both the *product* and *process* dimensions of biology are stressed. Thus effective biology teaching requires more than the following of a 'recipe-like' list of procedures, where content is presented from a textbook and the class managed effectively. Teachers need to interact with their learners (De Beer 1995:15; Killen 1998:*pers. comm.* and Meyer & Steyn 1991:21-36), so that learners can learn from a constructive perspective (Slabbert 1992:35), and structure their own learning environment where they can apply what they have learned (Poliah 1996:*pers. comm.*; Sanders & Doidge 1995:67 and Spady 1998:*pers. comm.*). Opportunities should thus be created where learners can think critically and develop skills to acquire information which they will remember for application in life.

In her study on the teaching of science by means of a process approach, Mossom (1989) stresses the importance of developing process skills. She concentrates on the primary school learner (one class) in South Africa, and developed a child-centred teaching method, based on a process approach and taught the same group of children over a period of four years. She then adapted the method continuously to conform to the needs of the developing children, and came to the conclusion that any learner can develop *process skills* (with the aid of meaningful subject matter) to learn for life at any stage of his/her development.

Mhlongo (1997) endorsed Mossom's study by conducting research in South Africa on the development of observation and related skills in the teaching and learning of natural sciences. By using thirty second year biology-student teachers at Tivumbeni College of Education, Mhlongo's main focus was to determine whether and how observation and related skills could be developed. His study indicated that students are not capable of making scientific observations without instruction, implying that process skills are developed through effective instruction.

Although the above mentioned research findings about the South African education system indicate the advantages of developing process skills, Slabbert (1993:38-40) is of the opinion that teachers are still emphasising content rather than focussing on the methods whereby to acquire this content. The reason for this can be relegated to many problem areas. To implement a process approach is not an easy task for those already otherwise involved.

1.2 THE PROBLEM

From the discussion on the previous pages, it is clear, that irrespective of innovative contributions by researchers as regards a process approach, biology teachers do not always implement it.

To encourage the successful implementation of a process approach in biology education, the factors that hamper the implementation should be studied. The fundamental question which stems from this problem is:

Why is a process approach not implemented successfully in the secondary school phase of biology education?'

According to certain educationists (Dekker 1996:*pers. comm.*; Fraser 1996:*pers. comm.*; Killen 1998:*pers. comm.;* Spady 1998:*pers. comm*. and Van Aswegen *et al.*1993:82) some of the main reasons why biology teachers do not teach learners process skills could be the following:

- A lengthy syllabus is time consuming.

- It is difficult to implement in large classes.

- There is a lack of resource material, data sources and apparatus.

- It is difficult to assess progress.

- Biology teachers contribute little as implementers of innovative ideas in biology education. Teachers and lecturers have delivered very little input when past changes in the curriculum were considered (Niebuhr 1996:*pers. comm.*). Important inputs that could have contributed to effective biology teaching were thus often ignored.

- Teachers in South Africa may not be able to implement a process approach, because of the lack of competency and adequate qualifications (Kriel 2000:*pers.comm.* and Fraser 2000:*pers.comm.*).

Successful implementation of a process approach for the biology curriculum, requires that attention be paid to the teaching methods used in biology; an improvement in biology teachers' qualifications and a modified teachers' approach to the teaching of biology.

The following issues elucidate the problem further:

- How can the factors that may hamper the development of learners' process skills be addressed?

- How can pre- and in-service training contribute to the successful implementation of a process approach?

- How can a variety of teaching and learning methods be used to facilitate the development of learners' skills?

- How can the principal, biology teachers and parents' participation in the implementation of a process approach be enhanced?

- How can the development of learners' process skills be assessed?

1.3 AIMS AND OBJECTIVES OF THIS STUDY

The aim of this study is to investigate, design and analyse sampled teachers' responses to questionnaires and interviews conducted with subject- and education specialists to determine why biology teachers are not implementing a process approach successfully in secondary school biology education. By using a process approach, learners should develop skills that will enable them to think critically when solving problems in real life situations.

The selection of this field of investigation necessitates the following inquiries:

- To identify the factors that may cause the high failure rate of learners.

- To explore the views of experts/specialists on the development of basic- and integrated process skills.
- To examine the opinions of recognised educators on the effectiveness of the inquiry method to develop process skills.
- To investigate empirically whether biology teachers are implementing the teaching and learning of process skills, and if not, why not?
- To determine problems teachers may encounter with the implementation of a process approach.

Guidelines will be formulated on how to implement a process approach successfully in the secondary school classroom. These will be based on the information gained through a literature study; qualitative interviews and questionnaires; and reasoning.

1.4 RESEARCH METHODOLOGY

Methods followed in this study are: a literature study; personal interviews and empirical research.

1.4.1 Literature study

The researcher reviews the theories and research of educators, which relate to problems in biology education and to a process approach. (Chapters Two to Five). The main reason for the literature study is to acquaint the researcher with the field of study and ensure effective empirical research, as well as to ascertain the current state of affairs in this area.

1.4.2 Empirical research

Empirical research has been undertaken to investigate why some secondary school biology teachers do not successfully implement a process approach and what the opinions of biology- and education specialists are on the implementation of a process approach.

1.4.2.1 Questionnaire

A questionnaire was issued to biology teachers (n=89) in secondary schools to determine whether or not they implement a process approach and if not, to determine possible reasons for the situation.

1.4.2.2 Presentation, statistical analysis and interpretation of data

Data collected by means of the questionnaire are presented in the form of tables. This is followed by analyses of data from which conclusions are drawn on why a process approach is not always successfully implemented in secondary biology education.

1.4.2.3 Personal interviews

Structured interviews were conducted with biology subject- and education specialists (n=19), to obtain information that can be used in the formulation of guidelines for the successful implementation of a process approach.

1.5 PROGRAMME OF STUDY

Following the pattern set out in the current orientation, the rest of the thesis is laid out as follows:

Chapter 2

The problems related to ineffective biology education are explored and a possible solution suggested.

Chapter 3

In this chapter the researcher describes a process approach and defines process skills by referring to basic- and integrated process skills.

Chapter 4

Possible advantages and disadvantages of a process approach for the biology learner and teacher are stated. The implementation of a new educational model (*Curriculum 2005*) in South African schools is explored and possible guidelines on how to assist the biology teacher with changes are suggested.

Chapter 5

Literature on the learning and development of process skills in the biology classroom by using inquiry as a method, is surveyed. Possible reasons as to why some biology teachers do not use inquiry methods, are also indicated.

Chapter 6

This chapter comprises the description of the empirical research and the interview methods. The actual empirical research and interview procedures, including the instruments for information collection, are reviewed in this chapter. The construction and administering of questionnaires and interview schedules used for this research are discussed. The sampling of biology teachers as respondents for this study is also illustrated in various tables. A list of open-ended structured questions used for the interviews with subject- and education specialists, are also reflected in this chapter.

Chapter 7

The responses of biology teachers' questionnaires are analysed and interpreted to determine why a process approach is not being implemented in the biology classrooms in Gauteng Province.

Chapter 8

Interviews conducted with biology subject- and education specialists to obtain information that can be used for the implementation of a process approach, are summarised. The responses from biology teachers (questionnaires) together with information gleaned from subject- and education specialists (interviews) are used to deduce the extent to which identified factors may hamper the successful implementation of a process approach.

Chapter 9

This researcher's findings, recommendations to improve the teaching of biology by implementing a process approach successfully as well as implications of these recommendations, are discussed.

CHAPTER TWO

FACTORS WHICH COULD CONTRIBUTE TO INEFFECTIVE BIOLOGY EDUCATION

2.1 INTRODUCTION

South Africa is encountering an ever-increasing shortage of biologists, (De Beer & Van Niekerk 1996:12; Department of Education 1994:23 and Van Rensburg 1994:88-90). According to De Vries, Du Plessis, Steyn and Viljoen (1992:32) and Papenfus (1995:59) this shortage can, in some instances, be relegated back to secondary school biology education, where biology learners are seldom actively involved in learning situations and where biology is abstractly taught without relating content to real life situations. Furthermore, the poor retention of biology content and the inability to apply knowledge in other subject fields of study, as well as the boredom which learners experience (notwithstanding their intellectual ability), indicate that biology education is neglecting the development of learners' intellectual skills (Mossom 1989:16). The development of intellectual skills is necessary since South Africa needs a citizenry which can think critically and respond intelligently to challenges and opportunities in everyday life situations, as well as global concerns.

The above mentioned problems can specifically be related to the high failure rate of Black biology learners (vide 1.1) and the large percentage of learners taking biology (85,16%)(Strauss, *et al.* 1994:10). The reason for singling out Black learners is based on the fact that numerically they constitute the major segment of the South African school population (79,26%)(Strauss *et al.* 1994:4).

In this chapter the problems that might cause the high failure rate of biology learners irrespective of the popularity of biology as a subject, will be identified. The Department of Education (1994:23) and National Qualifications Framework [hence N.Q.F.] (1996:5) are of the opinion that a solution to combat these problems will be to fulfil the goal of a democratic South Africa namely: '...to educate every citizen in order to learn for life'.

2.2 PROBLEMS IN BIOLOGY EDUCATION

As there have been such great demands for changes the past decade, the current biology education situation may be described as a crisis (Dekker & Van der Merwe 1990:1). The reason for these demands could be that the people of South Africa are not getting the type of biology education they need, especially as the future of the South African community is dependent on citizens who are biologically literate and who will be able to conserve nature and important resources for their descendants (Dekker 1996:*pers. comm.* and Poliah 1996:*pers. comm.*; Steyn 1993:3 and Vreken 1993:29). 'Biologically literate' implies that learners have developed the appropriate skills, knowledge and attitudes in biology education, which enables them to reason and solve problems adequately (Ziervogel 1995:23). Throughout a person's working life, situations and problems are encountered which have various possible solutions. Like other school subjects such as science, mathematics, history and others, effective biology education is necessary to enable learners to develop higher order thinking skills such as reasoning, inference, analysis, interpretation and problem-solving, which are invaluable in one's life (Adams & Callahan 1995:14-19 and Roth & Roychoudhury 1993:127). Although biology literacy is essential for all learners, the numbers of biology learners passing are still decreasing every year when taking into account the positive population growth of South Africans (vide 1.1) (EduSource Data News 1993:11-12).

According to De Beer (1995:18); Dekker (1996:*pers. comm.)*; Papenfus (1995:60) and Vermaak (1996:*pers. comm.*) this higher failure rate of biology learners could be caused by factors such as:

- The biology curriculum, which may not always keep up with changes as it may be exam-driven.

- The infrastructure for biology education, which may not provide in the needs of all learners (for example: large classes, lack of resources and many others).

- Biology teaching methods. Expository teaching and learning of biology content such as the lecture- and textbook methods, may still exist in biology education.

2.2.1 The biology curriculum

Basson (1996:*pers. comm.*); De Beer and Van Niekerk (1996:36); Dekker (1996:*pers. comm.*); Ferreira (1996:*pers. comm.*); Fraser (1996:*pers. comm.*); Poliah (1996:*pers. comm.*); Redlinghuys (1996:*pers. comm.*) and Slabbert (1993:38), point out that the current biology curriculum does not always address the needs of the community and the individual. Although the process of curriculum renewal have been set in motion, Jeevanantham (1998:217) argues that cultural experiences of Black learners are not included in the biology curriculum and might contribute to the high failure rate of Black learners. The senior secondary biology curriculum can be described as discipline-based, content-loaded and largely irrelevant to the majority of learners who will then not further their studies in a field of biology.

2.2.1.1 Discipline-based biology curriculum

For many years the academic discipline has been emphasised as the main source of teaching content for secondary school biology syllabi (Dekker & Van der Merwe 1990:2 and Ost & Yager 1993:282). By using the discipline of biology as a starting point, the needs of society become a secondary objective in biology education (Degenaar 1988:45-48 and Gibson & Gibson 1993:8-12). This implies that learners are introduced to the various fields of the discipline (as studied at university) and seldom to what is relevant to the needs of society. Notwithstanding changes made in Grade 7-9 biology syllabi the current senior secondary biology curricula in South Africa serve mainly those learners who may continue their education at tertiary level, specifically in the biological field (Spargo 1995b:30-31). Yet the majority of learners may not study a related field at tertiary level and fewer learners are opting for Higher Grade Biology. The statistics in Table 2.1 provided by Wadee (1999:*pers. comm.*) substantiate the latter.

Table 2.1 *Grade 12 biology candidates results for 1997 and 1998 in the Gauteng Province* (Wadee 1999:*pers.comm.*)

YEAR	NUMBER OF BIOLOGY CANDIDATES	
	HG	SG
1997	30910 (29%)	18779 (47%)
1998	22630 (37%)	25786 (45%)

Slabbert (2000 *pers. comm.*) states that the main purpose of teaching biology in school must be to spur learners' interest in such a way that they will become life-long learners not only of living organisms, but especially of social issues such as pollution; species depletion; waste disposal; environmental degredation; health related issues such as 'Acquired Immune Deficiency Syndrome' (AIDS); genetic engineering and many other aspects of life. Thus curriculum development could be approached from the perspective of society and not from that of the discipline. There is agreement among many biology educators that the present content-loaded syllabi do not achieve this purpose (De Beer 1995:18; Dekker 1996:*pers. comm.;* Niebuhr 1993:4-7 and Papenfus 1995:60).

2.2.1.2 Content-loaded biology curriculum

Doidge (1995:31) and Papenfus (1995:60) are of the opinion that the biology curricula in the senior secondary phase are overloaded with facts that cause the biology teacher to concentrate merely on the transmission of information while the development of important process skills such as observation; experimentation and the solution of problems, are neglected. The possible reason for this may be that the teacher is faced with a vast amount of content that needs to be taught and memorised by the learner for the final examination. This content is mostly irrelevant and learners are not able to apply what they have memorised to real life situations (Dekker & Van Der Merwe 1990:6-7).

Ferreira (1994:18) states that 80 percent of irrelevant facts are mostly forgotten within two years. Learners should thus rather acquire less knowledge and more application skills for long-term benefits. Learning opportunities should thus be created so that learners can develop skills whereby they are enabled to apply the content that they have learned. This supports Walch (1988:281) who criticises the teaching of low cognitive activities where mere content is covered, rather than engendering higher cognitive activities where learners learn to think critically and to apply what they have learned. What is taught in biology should be of enduring significance that could last for life.

Furthermore, teachers complain about the pressure to ensure that all content in the biology curriculum is covered (Dekker & Van Der Merwe 1990:2). The implied reason for this, is that the biology teacher believes that the current content in the curriculum is the content necessary to prepare learners for the exam. This is not true, as encyclopaedic knowledge is low on the priority list of competencies which are demanded by a dynamic society today (Slabbert 1992:35). Learners should rather develop skills which will enable them to acquire and apply knowledge, instead of the mere mastery of facts.

2.2.1.3 Irrelevant biology content and its effects

The South African population's view concerning their life standards and life style, is changing. As the population increases and the concern for technological advantages increases, the needs of the individual and the community is changing (Spargo 1995b:30-31). The biology curriculum also needs to change to address these needs constantly. De Beer (1996:26) refers to a lack of change by describing the biology curriculum as a 'dinosaur' in the twentieth century which is bio-technological, implying that the biology curriculum, as taught by many teachers, is not relevant for contemporary and future needs.

Schreuder (1991:24-28) elaborates further by arguing, that at the time when biology can and ought to be of the best service to human kind, we find that the biology curriculum is stuffed with information that has little potential for application. Jeevanantham (1998:218-219) argues that underqualified teachers, especially in rural areas, are struggling with curricula that are urban-biased and scattered with examples that are unfamiliar and inaccessible to the bulk of learners. The result of the increase of information is that the content which is taught, is not necessarily personally relevant to the learner and the learner is not able to apply this knowledge in everyday life situations (Adams, Charles, Greene & Swan 1985:463). A glimpse into the lives of secondary school biology learners finds them struggling through the complexities of photosynthesis; the Kreb's cycle; osmotic potential and sections through plants, while vital information that is related to the individual and the community such as pregnancy; tuberculosis; chronic bronchitis and asthma caused by air pollution, malnutrition, bilharzia, diseases caused by pathogens and many others, do not receive the necessary attention.

Consider, for example, the following content, as indicated by the syllabi of Grade 10 to Grade 12. (Departement Onderwys en Opleiding 1989)

Cross and longitudinal sections through the roots, stems and leaves (Grade 10 *Plant Anatomy*) - not only confuse learners and are difficult to learn, but are usually merely memorised by learners for examination purposes (Dekker & Van Der Merwe 1990:5-6).

In Grade 11, *Plant and animal structures, functions and habitat* cover more than two-thirds of the academic year, and have little application value in daily life. Most learners are not interested in the studying of plant and animal taxonomy (Viljoen 1992:52). Interest should rather be stimulated by exposing learners to relevant life issues mentioned earlier.

Plant physiology, photosynthesis, respiration, which appear in the Grade 12 syllabus certainly do not address the needs of the society and are difficult to understand.

According to Papenfus, De Beer and Dekker (1993:1-5) the gap that exists between the biology curriculum and the demands of a biological technology-orientated economy, urgently needs attention. However, some of the irrelevant content not only leads to needs of the community not being addressed, but can also affect the attitudes of learners, that might cause learners to respond negatively to biology as a subject and subsequently not furthering their studies in this field once they have left school.

(a) Disinterest of biology learners

It was already mentioned almost two decades ago by Millstein (1984:42) that biology, as '*...a subject that should be a joy and a lifelong stimulus to learn more of nature, has become a dreary drudge, a mountain of indigestible facts, however valid'*. Biology, with its vast amount of irrelevant content, can thus no longer be considered an interesting subject that addresses the needs of the individual and the community. According to De Beer (1995:18) traditional biology syllabi and teaching practices cause learners who are naturally interested in animals and the functioning of their bodies, to lose interest in biology as a subject. Thus learners acquire negative attitudes towards the subject as they progress scholastically.

The possible reasons why learners become disinterested and demotivated as they progress with their study of biology are:

- The vast tracts of irrelevant content (Dekker & van der Merwe 1990:6 and Papenfus 1995:60).

- The elements of surprise and marvel which are often neglected, due to an over emphasis on cognitive outcomes (Harper 1997:64-68).

- The learner's environment and content are remote from one another, and often incompatible (Dekker & van der Merwe 1990:6 and Jeevanantham 1998:218).

- Disruptions at school (De Beer 1995:19 and Van Vollenstee 1997:286).

A negative attitude also results in poor examination results which causes learners to regard biology as a difficult subject and discourages further studies in this field (Israelstam 1991:9; Klotz 1992:228; Moore 1994:4-5 and Papenfus 1995:60). Thus, the low numbers (vide 2.2.1.3[b]) of learners studying biology as well as the failure rate, could possibly be linked to the negative attitudes of learners. These negative attitudes cause many learners to lose interest in biology.

(b) Decrease in numbers of biology learners

According to Watson (1990:50) less than 1 percent of South African biology learners will further their studies in the field of biology. This is also supported by statistics provided by the Foundation for Research Development (1993:102). Although the numbers of learners opting for biology have always been high in proportion to other subjects, learner enrolment in biology is dropping. In 1986, 31 percent of all Grade 12 learners were enrolled in biology; in 1995 the enrolment for biology dropped to 24 percent (EduSource Data News 1997:18). According to Strauss *et al.* (1996:4) 48 773 learners were enrolled for biology in 1996 while in 1999 only 44 612 of the learners chose this subject (Strauss *et al.* 1999:12). Furthermore the Department of Education (1997a:3) indicates that one out of every five Black learners in South Africa chooses biology as a subject in Grade 10, and only a small percentage of them pass the subject. In 1992, 342 848 (77%) of the 447 904 Grade 12 learners were Black learners. Of these 342 848 Black learners, 50 791 (15%) wrote the biology examination and 24 965 passed. This means that only 6 percent of the Grade 12 Black learners who left school, passed biology on Grade 12 level (EduSource Data News 1993:11). Comparative figures indicate the wide gap between White and Black learners. In 1991, 43 percent White Grade 12 candidates opted for biology, and of these 98 percent passed.

A possible reason for the low numbers of Black learners that pass the Grade 12 examination could be that the needs and concerns of learners as future citizens are not sufficiently addressed in biology education (Doidge 1995:31 and Jeevanantham 1998:218-219). Biology education should enable all learners to satisfy their requirements and those of society. A further possible reason for the low pass rate of learners could be related to the poor infrastructure learners are exposed to in biology education. To be able to provide adequate biology education for all South Africans, the matter of infrastructure needs to be addressed as a problem area.

2.2.2 The infrastructure for biology education

According to the African National Congress (ANC) (1994:83) the infrastructure for biology education can be considered as inadequate to enable all South Africans to become biologically literate, especially in the senior secondary phase. Based on investigations conducted by several South African educators and educators from other countries, many teachers, especially in the rural areas, struggle to teach effectively because of the high teacher-learner ratio (1:60); a lack of equipment and laboratories to conduct experiments; a lack of copying facilities; a shortage of textbooks; sometimes no water and electricity supply; underqualified biology teachers; not enough school buildings; and many other factors (De Beer 1995:15; Degenaar 1988:45-48; EduSource Data News 1997:12; Harper 1997:12-16; Steyn 1998:182, Van Vollenstee 1997:263 and Watson 1990:49). Thus not all schools are equipped with the infrastructure needed to develop biologically literate citizens.

As biology is compulsory for Grade 8 and 9 learners in most South African schools, the problem of providing an adequate infrastructure is exacerbated by the ever-increasing population numbers. According to De Beer (1995:23) the total number of learners increases by 250 000 every year and an estimated 15 percent of all biology teachers leave the profession annually. This is higher than the supply of new biology teachers (EduSource Data News 1997:14).

The increase in the number of learners creates a need for 300 new schools and 800 new teachers (for all subjects) every year. The South African government is already using 20 percent of the country's budget for education and can hardly increase the budget to provide in the ever increasing need for education (De Beer 1995:23 and Niebuhr 1993:3).

Nevertheless, the infrastructure for biology education will have to improve to provide for learners' needs, especially those who leave school at an early age.

2.2.2.1 Biology education in rural areas

In many parts of South Africa, especially in the rural areas, large numbers of learners are not receiving any education (Harper 1997:26). Many of these learners are from poor families which live in isolation and are dependent on agricultural products for their survival (Lessing 1992:34).

According to Graaff and Gordon (1992:208) Black learners in the rural areas have been the most disadvantaged and ignored. Their school buildings, if any, are the most dilapidated, their resources the least adequate, the teachers the least qualified and the school situations, the least satisfactory. The school attendance of Black learners in rural schools is also unsatisfactory. In 1989, 475 000 (26%) of the Black learners were enrolled in rural schools of the Department of Education and Training (DET). Statistics also indicate that up to 36 percent of learners between the ages of 6 and 14 were living on farms and did not attend school (Harper 1997:26). Those who did attend school were not necessarily taught biology, as 174 South African schools do not offer Grade 8 biology (EduSource Data News 1997:17). The consequence is that the flow of learners to biology in the higher grades, is affected.

With South African Black schooling in rural areas having a large number of learners and at present being both the most disadvantaged and neglected educational sector, it is essential that the Government pay special attention to schooling in rural areas. Learning opportunities will have to be created to enable all learners to develop the skills they need to become life long learners. To be able to develop these learning skills, it is imperative though that biology teachers are qualified and adequately trained (Department of Education 1995:30).

2.2.2.2 Teacher qualification

The qualifications of teachers can be regarded as another critical problem in biology education. Inadequate teacher training could not only cause the lack of interest in biology as a school subject but also influence the success rate of learners (Kriel 2000 *pers. comm.*). Further problems such as the decrease in the number of qualified and competent biology teachers (Fraser 1996:2) and a poor implementation of innovative ideas exacerbate the situation (De Beer 1995:6; EduSource Data News 1997:35 and Kahn 2000:8). The success of any education system depends on quality teaching and competent qualified teachers (Fraser 1996:2 and Kriel 2000:*pers. comm.*).

According to a report compiled for the Department of Education and Training, only 42 percent of all biology teachers have been formally trained in biology and over half of those with subject qualifications gained through Secondary Teacher Diploma courses (EduSource Data News 1997:33). While university training is recognised as more appropriate for teaching at the senior secondary level, only 16 percent of biology teachers have university training in biology (EduSource Data News 1997:33).

The following table reflects the qualifications of biology teachers across seven provinces (Eastern Province, Free State, Gauteng, KwaZulu Natal, Northern Province, North West and Mpumalanga) in South Africa in 1996.

Table 2.2 Qualifications of biology teachers across seven provinces (EduSource Data News, 1997:33).

QUALIFICATIONS OF BIOLOGY TEACHERS	NUMBER OF TEACHERS QUALIFIED IN BIOLOGY	% OF TOTAL BIOLOGY TEACHERS
University course of three or more years	1192	8%
Two-year university course	360	3%
One-year university course	701	5%
Higher diploma of education (biology)	427	3%
Secondary teacher's diploma (biology)	3208	23%
Total qualified	5888	42%

Of the seven provinces mentioned, Gauteng biology teachers have the largest number of adequately trained teachers, as 62 percent have qualifications in biology. Of those, 40 percent have had at least two years university training in the subject (EduSource Data News 1997:33). The Northern Province has the worst record when compared to other provinces. According to the data almost 60 percent of the biology teachers have no recognised training in biology (EduSource Data News 1997:33). The majority of those who are trained have a Secondary Teacher's Diploma. This diploma may consist of one, two or three year courses, at the most equivalent to a first year level university course.

The report compiled for the Department of Education and Training further indicates that there might be a relationship between qualifications of biology teachers and learner results in the various provinces, although this is not consistent for all the provinces (EduSource Data News 1997:33). In provinces where biology teachers have a poor subject knowledge and a high learner/teacher ratio, learner performance in the Grade 12 examinations tends to be poor. This statement is endorsed by the following table from the 'Race Relationship Survey' which was compiled in 1990 (De Beer 1995:6).

Table 2.3 *The influence of qualified biology teachers on the Grade 12 pass rate of biology learners* (De Beer 1995:6).

	QUALIFIED BIOLOGY TEACHERS	GRADE 12 PASS RATE PERCENTAGE OF BIOLOGY LEARNERS
Gazankulu	41%	36%
KaNgwane	27%	38%
KwaNdebele	36%	29%
KwaZulu	33%	43%
Lebowa	40%	28%
QwaQwa	27%	31%
Bophuthatswana	32%	52%
Ciskei	35%	43%
Transkei	49%	44%
Venda	51%	40%
Coloureds	59%	79%
Whites	98%	96%
Indians	98%	95%
Blacks	37%	37%

Table 2.3 indicates that the previous Indian and White Education Departments were staffed with qualified biology teachers and had a commensurate pass rate, while the Black education had less qualified teachers and a lower pass rate. It therefore appears as though the qualifications of the biology teacher could influence the pass rate of learners. This statement is supported by a survey on the qualifications of biology teachers that was conducted in the Mankweng circuit (30 kilometres north of Pietersburg). It was found that only 2,8 percent of the

Grade 12 biology teachers had a B.Sc. degree, 25,7 percent had a BA degree and 14,3 percent had incomplete degrees. The majority of Grade 12 biology teachers (57,1%) had no academic training (Ferreira 1994:17). When comparing the figures of qualified teachers with the pass rate percentage of biology learners in Table 2.3, there seems to be a link between the failure rate of learners and qualified teachers. It therefore appears as though qualified teachers may contribute to a higher pass rate.

According to the Department of Education (1995:30); National Education Policy Investigation (hence NEPI Report) (1997:5) and Slabbert (1997:12), the Ministry of Education is convinced that the most efficient method to improve the quality of teaching and learning will be to upgrade the teacher training programmes. In-service and pre-service teacher training demands intensive attention to combat the shortage of qualified biology teachers. Teachers thus need to be trained and qualified to ensure effective biology teaching.

The training of biology teachers also implies that the role of the teacher should be clear to the trained teacher (Bodenstein 1996:52-58 and Suzuki 1984:294-322). This will enable the teacher to execute his/her role responsibly and to select the best possible teaching methods.

2.2.3 Biology teaching methods

The teaching strategy and the specific teaching methods which biology teachers use to unfold learning content, should enable learners to become life-long learners (Department of Education 1994:4). The biology curriculum and the Senior Certificate Examination in biology may force the biology teacher to use formal teaching methods with the aid of a textbook, where the learners observe passively (Hockey 1995:77-80; Papenfus 1995:59 and Vermaak 1996:*pers. comm.*). Learners thus do not get the opportunity to develop process skills by means of an inquiry method. The formal methods of teaching are in contradiction with the aim of biology education namely: '...to educate every citizen in order to learn for life' (Department of Education 1994:4).

According to Mhlongo (1997:4) and Van Aswegen *et al.* (1993:76) the present teaching and learning of biology is largely expository in character.

2.2.3.1 Expository learning and teaching of biology content

Expository teaching implies that knowledge is obtained from an authoritative source, which may be a worksheet, a teacher, or a textbook (Van Aswegen *et al.* 1993:75). According to the opinions of Chacko (1993:47); Matlock (1995:167-168) and Tobin *et al.* (1994:51) authoritative teaching results in learners concluding that biology is based on authority. The implication is that it is sometimes too difficult for the common person to understand the concepts, unless explained by an 'authority'. Learners are thus seldom given the opportunity to learn biology the way a practising biologist experiences it. Yager and Huang (1994:98) elaborate by arguing that an expository teaching strategy sometimes fails to provide the opportunity for learners to develop a rational basis for applying biological knowledge to their own daily lives, and for interpreting current technological innovations.

Consequently learners might hardly ever, receive the opportunity to handle material and apparatus, to follow instructions and logical sequences, or to acquire practical experience of the biological way of thinking (Leonard, Fowler, Mason, Ridenour & Stone 1991:400). The content-loaded curriculum does not always allow time for the development of process skills to enable learners to think critically when solving problems (Leonard *et al.* 1991:400; Preethlall 1996:133 and Sanders & Doidge 1995:130-133). It can be said that teachers use expository methods such as the lecture and textbook method to cover a vast amount of content in the least possible time to enable learners to perform well in tests and examinations (Dekker & Van Der Merwe 1990:3).

The lecture and the textbook methods can be regarded as the methods most commonly used by the biology teacher (Van Aswegen *et al.* 1993:76).

(a) The lecture method

The lecture method, where the teacher talks, explains, illustrates and defines while the learner listens passively, is often used to present content to large classes (Chacko 1993:47). Most teachers find it extremely difficult to do individual work with large numbers of learners within a specific time frame. Individual work demands sufficient apparatus, time and equipment, and a lack of these might cause biology teachers to refrain from using the individual method and rather to adhere to the lecture method (Chacko 1993:47 and Van Aswegen *et al.* 1993:76). Isaac (1990:66) is of the opinion that the lecture method is used more frequently by the majority of biology teachers, because of time constraints and due to the cost in terms of equipment, space and supervision required by the practical or investigative methods.

In spite of the advantages to the lecture method mentioned above, many researchers criticise the method. Huang (1991:26); Isaac (1990:66-67); Matlock (1995:167-169); Van Aswegen *et al.* (1993:75) and Yager and Huang (1994:98-100) maintain that it is doubtful whether the lecture method alone is sufficient for the development of skills that learners need to learn for life. Yager and Huang (1994:99) describe the lecture method as a 'sterile' learning method, which prevents learners from exploring, thinking or interacting. Learners are sometimes taught as though they are passive and non-curious receivers of knowledge (Tobin *et al.* 1994:50). Learners are not always given the opportunity to develop the skills they need to acquire and apply the information they have learned. Since learners are not always actively involved in the learning activities, lessons can easily become boring, and learners may find it difficult to remember data.

(b) The textbook method

Various reports of researchers such as Chacko (1993:47); Harper (1997:17); Mhlongo (1997:3); Samuels (1995:87-89) and Slabbert (1992:35) indicate that the teaching and learning of biology in South Africa is plagued by teacher-dominated and textbook-bound methods.

From these reports the following criticisms against the textbook method are listed:

- Apart from the new Grade 7-9 biology syllabi (*Curriculum 2005*) the current content-orientated senior secondary biology taught in South African schools sometimes force teachers to simply repeat the content which is written in learners' textbooks. This can be regarded as a waste of time as learners can learn content in textbooks on their own.

- Much of the content written in textbooks has become outdated or/and incomplete because of new developments in biology. Content knowledge is thus tentative, as technological and scientific developments necessitate that the facts in textbooks should change accordingly.

- Most South African textbooks lack open-ended problems which learners can investigate and find solutions to as part of developing skills to learn for life. Biology teaching should move away from a textbook-centred approach, where only the biology content is considered, and not the skills necessary to apply this information.

Textbooks as such, are useful sources of information, but they are mostly misused as mentioned earlier. Most South African teachers use textbooks as the only source of information (Slabbert 1992:35). Thus the learner might be separated from the concrete sources of knowledge, such as the materials of the environment where sufficient relevant information can be gained.

From the discussion of problems on the preceding pages, it is evident that serious problems exist in current secondary school biology education in South Africa. The suggested aim '... to educate every citizen in order to learn for life' (Department of Education 1994:23 and NQF 1996:5) is not achieved. Whatever the constraints of biology education are, it is imperative that solutions be found to improve biology education. All biology educators need to use an approach that will enable learners to develop learning skills which they need to solve real life problems and which they can integrate in other subject areas.

2.3 SUMMARY

The high failure rate of Black biology learners, and the small percentage of learners who further their studies in biology, can be related to several factors that contribute to ineffective biology education, namely:

- *The biology curriculum* which is discipline-based, loaded with content, and sometimes irrelevant to the majority of learners.
- *The infrastructure* of most rural schools which does not always provide the means to teach effectively.
- *The teaching methods utilized* which are largely expository in character implying that the teacher uses a textbook to teach while the learners observe passively. Teachers prefer to use the lecture- and textbook method to cover a vast amount of content.

Contemporary biology education resembles a conflict between theory and practice. Learners receive a vast amount of knowledge but do not know how to apply this knowledge to their daily lives. To counter the above mentioned problems the Government will possibly need to use an education system which is skills-orientated, and which enables learners to apply the skills they have learned in all other subject areas to solve individual and community problems. It is imperative that an approach should be used so that all learners can acquire a functional biological education that will benefit the individual and the community. The future of any country is dependent on its citizens who should be well educated and trained to become responsible members of the community.

Consideration should be given to changing to a more *learner-centred* approach, where learners are given the opportunity to develop skills through a process approach, which will enable them to acquire and apply knowledge in real life situations. A process approach, which consists of basic- and integrated process skills and critical thinking skills will be discussed in the next chapter.

CHAPTER THREE

REASONS FOR USING A PROCESS APPROACH IN THE TEACHING AND LEARNING OF BIOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to describe an ideal approach based on various educationists' opinions which may contribute to effective biology education and possibly address the problems discussed in the previous chapter.

As South Africa needs an education system that will prepare all learners adequately and enable them to solve future problems it is essential to develop learners' skills to cope with these issues (Fraser 1996:13 and Schreuder 1991:24-28).

In this chapter a process approach is described that can be used to develop learners' basic- and integrated skills during biology education. As an understanding of process skills and how they can be included in the biology curriculum is essential to implement a process approach, basic- and integrated skills and activities on how to develop these skills in the biology classroom, will be discussed.

3.2 WHY A PROCESS APPROACH?

From the discussion in Chapter Two on the factors that might influence biology education, it becomes evident that an approach is needed where money, infrastructure, cultural background and resources do not hamper effective biology education. As the South African population increases, the demand for qualified biology teachers will also increase (vide 2.2.2.2). Because of the shortage of qualified biology teachers, teachers will have to get accustomed to teaching large classes with limited biology resources, cope with a lack of discipline, an inadequate infrastructure and extended teaching hours (De Beer 1995:34 and Fraser 2000:*pers. comm.*). Lewis and Kelly (1987:83) are of the opinion that in spite of such constraints, one of the most important aims of biology education should not be forgotten, namely: 'to teach learners to understand nature in order to change it with a view to satisfying human needs, but at the same time, ensuring that minimum damage is done to nature's delicate balance. Biology education should aim to instill curiosity and a desire to know (Roth & Roychoudhury 1993:127-131). It should engender the questioning of all things and a search for information that can be applied to solve problems (Stewart 1987:2). Learners should be able to make wise independent decisions, which means that they will need a large fund of information and the skills to apply this information (James & Kurtz 1985:62; Ost & Yager 1993:284 and Rakow 1988:141-154). Biology education should prepare learners for life and for careers (Hickman & Kahle 1982:360 and Pepper 1995:1-10). To meet these requirements, a new approach to biology education on all levels is needed.

If it is accepted that biology teachers are preparing learners for life and future careers, then it becomes imperative that they investigate and address the demands of the future world. South Africa needs an education system that will prepare all learners adequately and enable them to solve future problems efficiently (Schreuder 1991:24-28). Therefore, effective biology education is essential to equip school leavers to understand contemporary and future bio-social issues and with the necessary skills and knowledge to handle these issues (Fraser 1996:13 and Gauteng Education Department 1997:5-8). Skills and knowledge are critical for learners to be productive in both small and large-scale enterprises once they leave school (Reconstruction and Development Programme [RDP] 1994:96). It is important that biology education should provide opportunities where learners can develop skills they need to learn for life. An ideal approach to teach and learn biology, can be described as an approach which takes the teacher's, the individual's and the community's needs into consideration (Watson 1990:49). An effective and successful biology teaching and learning approach, resides in the ability of the approach to prepare learners for their roles as citizens, consumers, employers and parents, in a developing South Africa. Learners should be able to function independently and responsibly.

World wide traditional approaches to biology education have focussed on the teaching of factual knowledge, with very little attention being paid to teaching higher order activities such a reasoning, creative thinking and problem solving (Adams & Callahan 1995:14-19). To enable learners to develop these skills, learning and teaching cannot take place through passive handling and acquiring of information. According to the opinions of several educationists active and significant learning should be prompted through an approach where fewer facts are selected, interpreted and conveyed in association with the learner's previous experiences, contemporary needs and knowledge structure (Arena 1996:35; Dekker & Van Der Merwe 1990:3; Mhlongo 1997:3-7; Mossom 1989:15-18; Sanders & Doidge 1995:130-133; Slabbert 1992:35-38; Van Aswegen *et al.* 1993:14 and Wellington 1989:8). Biology teaching and learning should not be bound to the textbook and learners forced to master a certain amount of content for external examination, but biology teaching should be inquiry-based to enable learners to develop the skills needed to *acquire* and *apply* information (Gayford 1989:193; Germann 1991:243 and Tamir & Amir 1987:137). This implies that more emphasis should be placed on process skills where learners develop the ability to think critically and solve problems by means of inquiry activities rather than memorising 'facts' and 'theories' which are isolated from the context in which biology is taught. Active and significant learning could take place through a process approach where the teacher selects, interprets and conveys less facts to learners, according to their experiences, needs and knowledge structure (Moll & Allen 1982:95 and Wardle 1985:26-29).

Supporters of a process approach in South Africa's educational system include Ferreira (1996:*pers. comm.*); Poliah (1996:*pers. comm.*); Mhlongo (1997); Mossom (1989); Niebuhr (1996:*pers. comm.*); Redlinghuys (1996:*pers. comm.*) and Vermaak (1996:*pers. comm.*).

Niebuhr (1996:*pers. comm.*) argues that the contemporary content-loaded biology curriculum should be replaced by one that encourages a process approach which will enable learners to obtain certain outcomes by the end of their school career. Vermaak (1996:*pers. comm.*) elaborates on Niebuhr's view by proposing that learning opportunities should be created for learners to develop skills, without forcing them to master vast amounts of information. Sanders and Doidge (1995:131) are of the opinion that there is an increasing demand among biology educators to use a skill-based curriculum rather than a content-orientated one. Although many South African biology educators are for the idea of a skill-oriented biology curriculum, very little is done in some classrooms. In the past two years some efforts have been made to familiarise learners and teachers with the learning and education of skills. Through the Independent Examinations Board (IEB) a Biology User Group (BUG) was formed which worked on a curriculum in which the teaching and assessment of skills are emphasised (Sanders & Doidge 1995:132).

A process approach should be used so that learners leaving school at an early age will also be able to solve personal and community problems. It is imperative that the basic- and integrated skills learners need to learn for life are developed in the early years of learners' education, prior to leaving school.

3.3 THEORETICAL FOUNDATION OF A PROCESS APPROACH

Various learning theories which were modified continuously contributed to the development of a process approach. The most important contribution to biology education is the addition of a new dimension to biology teaching, namely the development of process skills. The need for this dimension is borne out by the theories of Piaget, Bruner, Gagnè and Ausubel (Mossom 1989:127).

Piaget's theory of the 1960s and 1970s is based on the ways which learners use to develop knowledge. Piaget maintains that the purpose of education should rather be to develop learners' intellectual skills to acquire information rather than to overload learners with content (Fraser 1984:43).

Bruner emphasises the heuristics of discovery. According to Bruner's theory every teacher should take three processes namely acquisition of skills, transfer of skills and the evaluation of skills, into account when planning the structure of his/her lessons (Bruner 1960:60).

Gagnè identified conditions for learning and strategies for teaching. His ideas are illustrated in the 'Science- A Process Approach' (SAPA), an American programme. Gagnè's proposals on the development of learners' process skills have been the most influential in the development of the SAPA programme. Gagnè views the nature of scientific inquiry as a set of activities characterised by a problem-solving approach in which each newly encountered phenomena becomes a challenge for thinking. Thinking begins with careful observations, proceeds with measurements required, distinguishes between what is observed and what is inferred, and draws reasonable conclusions (Finley 1983:48).

Kuiper (1998:112) supports the theory of Gagnè, Bruner and Piaget by stating that biology education should move away from content-based curricula towards constructivist, contextualised and process-based curricula that will consider cultural differences when developing curricula.

The multicultural nature of South-African education demands an approach that will include themes, activities and outcomes, related to the learner's everyday life and encourage learners to become participants in the learning process. Social constructivism enables the teacher to use knowledge through processes which are socially, culturally and politically based. Learners can construct a culturally and meaningful understanding of biology by using different perspectives, experiences and values of their fellow-learners.

By considering different cultural backgrounds of learners when implementing a process approach, learners may become biology literate citizens who are able to use science for their own and the society's benefits.

Ausubel on the other hand criticised the emphasis on discovery and inquiry and claims that, unless meaningful learning is provided through a suitable teaching method, learners will learn by rote. According to Ausubel (1968:255) it is much less time consuming to communicate and explain an idea meaningfully to others than to have them rediscover it for themselves. Learners should possess relevant prior concepts so that new knowledge can be continuously integrated into the existing cognitive structure. If prior relevant concepts have not been formed, then rote-learning will result independently of whether reception or discovery methods are used. Notwithstanding some discrepancies between the different theories mentioned above all contributed in some way to the development of a process approach.

3.4 DEFINING A PROCESS APPROACH

Although principles of the Biology Science Curriculum Study (BSCS) which was established in 1959 in the United States contributed to the development of a process approach, it was originally conceived and developed by the American Association for the Advancement of Science, as SAPA (Carin & Evans 1984:372 and Mossom 1989:149). This project was developed in the 1960s and clearly defines science as a set of processes, while de-emphasising the content position. By defining science as a set of processes by no means eliminates the learning of concepts (Schilling, Hargreaves, Harlen & Russell 1990:26). When teaching biology, processes should not be mastered in a vacuum, but should always be related to content.

Mossom (1989:18) defines a process approach as '...an approach to teaching science in which the intellectual changes necessary for the understanding of concepts involved are given due consideration....', while Martin, Saxton, Wagner and Gerlovich (1997:11) describe a process approach as the *processes* used to enhance the critical thinking ability of learners to enable them to solve problems (vide Figure 3.1). A process approach refers to the *processes* used when teaching biology, that enable learners to develop intellectual skills to process information. By using *processes* the intellectual ability of learners is developed, which enables them to acquire and apply information in real life situations. A possible model of a process approach is illustrated in Figure 3.1.

Figure 3.1 Model of a process approach

processes
↓
critical thinking
↓
process information
↓
apply in real life situation

3.4.1 Processes

According to SAPA, *processes* are defined differently because of several interpretations of the concept. Arena (1996:34); Carin and Sund (1997:7) and Screen (1986:4) point out that a scientist uses a variety of empirical and analytic procedures in his/her effort to clarify the mysteries of the universe. These procedures (*processes*) are measuring, solving problems and implementing thoughts and many others. *Processes* can be considered as the sequence of events which scientists use while taking part in a scientific investigation. By teaching learners how to use these *processes*, they will be able to look at and deal with the world in the way that scientists do.

The major features of processes are proposed by Gagnè (1963:144) as follows:

- A process is a specific skill that is used by scientists to understand any phenomenon.

- A process is an identifiable behaviour of scientists that can be learned by learners.

- A process can contribute to rational thinking in every day affairs as processes are transferable to different content domains.

Abruscato (1988:39) and Finley (1983:48) describe a *process* as a specific intellectual skill, which is used by all scientists and can be applied to understand any phenomenon. *Processes* are broadly viewed as ways whereby information can be processed with the aid of learners' intellectual skills. Such processing grows more complex as the individual develops.

Skills are often referred to as *processes*, although these are not the same. Therefore definitions of 'processes' and 'skills' are important to differentiate between the two concepts.

3.4.2 Defining skills and processes

In a process approach, the complex set of processes a scientist uses in conducting a scientific investigation are broken down in a number of skills which must be mastered if the learner is to develop a sound knowledge of science and its methods (Mossom 1989:69). *Processes* are the ways of thinking, solving problems and using thoughts. Hawkins (1988:643) describes a process as 'a series of actions or operations used in making, manufacturing, or achieving something'. A process is seen as a rational activity involving the application of a range of skills (Wellington 1989:99).

Skills can be described as the ability to think and reason when required to do so (Goh, Toh & Chia 1989:430-432). According to Harlen and Adey (1986:707) a skill can be defined as any cognitive process involving any interaction with content. Abruscato (1988:6) and Wellington (1989:18) describe skills as the action of scientists as they 'do' science. A *skill* is an individuals' contribution to a learning activity or contribution in achieving an objective. A skill can be identified as being separate from a process. A skill can be defined as 'the ability to do something well, the use of practical knowledge and power' (Hawkins 1988:764). Thus we can speak of a specific skill, for example a reading skill, a predicting skill, an observing skill, manual skills and others. Wellington (1989:99) describes a skill as a specific activity which a learner learns to do. A characteristic of a skill is that it can be a visible action (both broad on specific) and can be assessed.

Goh, Toh and Chia (1989:430-432) are of the opinion that processes are the ways of thinking, solving problems and using thoughts to gather information; while skills can be described as the thinking and reasoning required to do so. By implication a process is a much broader concept than a skill. A skill can be seen as a sub-division of a process. A *process* is a more general means to an end (Watts 1994:13). So, for example, the ability to describe an event accurately, can be defined as a 'skill', whereas a 'process' is the provision of an accurate description. Skills refer to a process which has a certain outcome (Jessup 1991:121).

It is, however, not always clear where processes start and skills end. Some researchers combine the two words and refer to 'process skills'. Process skills can thus be defined as intellectual skills used by learners to process information (Mossom 1989:31). Several terms have been used to describe process skills. These are 'scientific method'; 'thinking' and 'critical thinking skills' (Champagne & Bunce 1991:209). Today, however, 'process skills' is a broad expression commonly used and will be used in this study.

3.4.3 Process skills

By using a process approach the learner should acquaint himself/herself with a number of process skills which a scientist uses in conducting an investigation (Brotherton & Preece 1996:65-74 and Van Aswegen *et al.*1993:17). By emphasizing science process skills learners discover meaningful information and accumulate knowledge by constructing their ideas in and out of the biology classroom (Martin *et al.* 1997:15). The assumption is that by using process skills learners will be able to acquire and apply knowledge to different situations.

SAPA divides process skills into basic- and integrated skills. *Basic process* skills, such as observing; inferring; classifying; measuring; predicting and communicating, can be described as simpler skills that a learner uses from pre-primary school up to Grade 5 (Baird & Borich 1987:259-269; Cavendish, Galton, Hargreaves & Harlen 1990:101 and Van Aswegen *et al.*1993:17). Primary school learners should develop basic skills carefully and use them systematically, as a necessary preliminary to undertaking more complex science learning in the later grades.

Integrated process skills are dependent of the learner's ability to think on a high level and to consider more than one idea at the same time. The term 'integrated' implies that various of the basic process skills can be combined to solve problems.

Integrated skills follow on after the learner has mastered basic process skills. Integrated process skills are skills needed to execute scientific experiments. These skills, such as defining operationally; interpreting data; controlling and manipulating variables; formulating a hypothesis and experimentation are advocated in the higher grades, which implies that the learners in the lower grades might be too immature to cope with these skills (Mossom 1989:72).

3.4.3.1 Basic biology process skills

As an understanding of process skills and how they can be included in the biology curriculum is essential when implementing a process approach, basic- and integrated skills will be described in an attempt to define process skills. After each description examples of how the particular process skill can be developed through biology activities will follow.

(a) Observation

Observation is the primary process through which learners obtain information (Van Aswegen *et al.* 1993:86). The ability to observe accurately can be described as the most basic process skill, since it is the basis for the development of other important process skills such as inferring; predicting; measuring and so forth (Mhlongo 1997:145). All the other process skills, as discussed in the rest of this chapter, should be regarded as skills linked to observation, since observation plays an indispensable role in all of these skills.

The skill of observing, includes all five senses namely: seeing; hearing; feeling; smelling; and tasting, with or without the aid of instruments (Cavendish *et al.*1990:22 and Gott & Welford 1987:219). Observation is an empirical process of biology investigations, based on practical experiences without regard to inference or theorising. The ability to observe needs to be acquired/learnt, and learners can be trained to observe accurately, systematically, logically and precisely, in their measurements (Van Aswegen *et al.*1993: 86).

The biology teacher has the important task to create opportunities such as experimentation, dissections, fieldwork, excursions and other opportunities, where learners use all their senses to observe, objects or events, to help them notice how things may be alike or different, and to help them become aware of changes (Zeitler & Barafuldi 1988:97). The effectiveness of these opportunities will always depend on accurate observations. Learners can develop their observation skills in various ways.

The biology teacher could, for example, supply earthworms to each learner, or group of learners, to observe. After the learners have had an extensive exploration time, they would probably be ready to begin a more detailed analysis of the earthworm. The biology teacher could provide learners with a list of questions to answer.

Questions could include:

1. How does the earthworm feel when you touch it?
2. What colour is the earthworm?
3. How long (in centimetres) is your earthworm?
4. What does your earthworm weigh?
5. How many legs does your earthworm have?
6. Describe its head; does the earthworm have eyes?
7. Compare two earthworms; can you tell them apart? How?

Biology investigations start with observations of the natural world. These observations may take place from a framework of prior knowledge. What learners or biologists look for in a situation and how they interpret what they see depends largely on the relevant knowledge they bring to the situation, no matter how incomplete that knowledge might be. After identifying the information, it is classified into known categories of the object or processes they are investigating. (Van Aswegen *et al.* 1993: 15). More complex observations can be made where learners distinguish, differentiate and systematise the information gained from such observations. To be able to make more complex observations, learning activities used for observational development should provide for the use of several other skills such as communicating; classifying; inferring; and others.

As observations and inferences can easily be confused, observations can be described as statements about information that is available directly through the five senses, while inferences are interpretations of these observations.

(b) Inference drawing

Inference drawing can be described as interpreting, or the drawing of a conclusion from what is observed (Hester 1994:118). Inference is based on prior knowledge and experiences and is formed by three interacting components, namely, observation, prior knowledge and experiences and conclusions (Carin & Sund 1989:68 and Zeitler & Barafuldi 1988:97). For example, after observing the respiratory organs of several fishes, learners can make a general statement that 'fishes have gills'.

When observations are made, knowledge and experiences are organised mentally into a scheme. A scheme is a mental framework, network or construct of related details organised around a familiar event, theme or process (Carin & Sund 1989:68). When a new situation is observed with elements similar to a previous situation, the scheme is used to facilitate the interpretation of the new situation (Carin & Sund 1997:9-12). A scheme can be used to guide inferences about incomplete information. For example: Learners could be asked what they observe and what they infer from their observations. Consider the following examples:

Observation: *The colour of the leaves of the pot plant vary from green to yellow.*
Inference: The plant is getting too much water.

Observation: *Blue litmus paper used to test for the pH of soil turns red in colour.*
Inference: The soil is acidic.

This test also assesses learners' ability to distinguish an observation (blue turns red) from an inference (acidic) (Mhlongo 1997:183-185). An inference refers to those events which are exposed to questioning analysis.

The broader the learners' range of knowledge and sensory experiences, and the more carefully they observe and sift through their observations for relevant cues, the more powerful and accurate their inferences are likely to be. Consequently, inferences reach beyond the evidence, in an attempt to explain a set of observations.

(c) Classification

Classification can be described as the grouping of objects according to similarities and differences, or according to an established pattern (Abruscato 1988:31; Hester 1994:86 and Mayer 1987:32). Learners classify objects and events on the basis of perception and recognition, in other words on the basis of observable similarities and differences in properties selected for a specific purpose.

It is part of human cognitive processes to classify objects into groups and sub-groups (Abruscato 1988:31). At a very young age learners start classifying informally or artificially (Miller 1989:53). By using a few characters, for example, learners can classify different leaves according to their characteristics, such as shape, veins, simplicity or complexity. When teaching learners how to classify animals and plants the objective is not to make a complete study of plant and animal taxonomy, but rather to focus their attention on the variety of plants and animals and to stimulate their interest in all organisms of nature. As their knowledge structure expands as they gain more experience in the process of classifying, learners will be able to use a more complex classification system to sort organisms into groups on the basis of their overall evolutionary relationship (Pugh & Dukes-Bevans 1987:21 and Van Aswegen *et al.* 1993:16). A questionnaire can be used to identify unknown organisms for classification purposes. For example the following questions could be included in a questionnaire to aid this exercise:

1. Into how many parts is the body divided?
2. How many wings are present?
3. How many pairs of legs are present?
4. Where are the legs connected to the body?
5. How many eyes can be observed? And other questions.

The answers to these questions could then be used to develop a dichotomous key to distinguish between the organisms.

(d) Communication

A very important skill of a process approach is the ability to communicate data to others (Funk, Fiel, Okey, Jaus & Sprague 1985:57). The communication skill implies that one person transfers information to another, by using language, drawings, graphs and others, to express his/her thoughts in ways that others can understand (Mhlongo 1997:105). Clear precise communication with others is essential to all human endeavours, since communication is the basics to everything we do.

Communication includes the use of words or graphic symbols to describe an action, object, or event (Wolfinger 1984:61). Language development, drawing ability, facial expressions, acting, and reading readiness are also closely related to the ability to communicate effectively (Albers 1988:12). Recording, where learners use bar graphs, models and charts to communicate, is also a form of communication. The ability of a learner to record and communicate his/her work, is a prerequisite for critical reflection (Carin & Sund 1989:69). By means of language, learners are able to record and evaluate observations.

The biology teacher can develop learners' communication skills by encouraging them to describe objects and events in detail, and to record information from an experiment in tables and graphs and to report their findings to the rest of the class. When learners discuss their findings, the biology teacher should ensure that useful and not trivial details, are discussed (Carin & Sund 1989:69). These discussions enable learners to develop the communication process skill.

When learners have mastered the communication process skill, they should be able to transfer the information they have gathered into communication statements (Albers 1988:12). For example, learners can view a video or read articles on AIDS and its effect on people. The biology teacher could then give learners an assignment to write down comments on the following statements:

- I agree with the minister of health that AIDS can be prevented.

- I disagree with the minister of health that nothing can be done to cure AIDS patients.

Once the learners have completed the assignment they discuss their answers with the rest of the class. From these discussions the class could then decide whose statements are correct while the biology teacher acts as facilitator.

Without communication the learning of processes has no value, because nobody would know what has been observed if observations cannot be communicated to others.

(e) Measurement

To measure is to compare things (Zeitler & Barafuldi 1988:97). Comparison is the basis for all measurement. In biology one often needs to compare the size of objects, the areas, weight and temperature.

Thinking about properties in a quantitative way, naturally leads to measuring them (Martin *et al.* 1997:13). Measurement enhances thinking by adding precision to observations, classifications and communications. Learners can be encouraged to measure by using tools, such as rulers, meter sticks, balances, measuring cylinders, clocks, calculators, computers, electrical instruments and even arbitrary units such as marbles, paper clips and many others, to measure quantity, distance or speed. A biologist who has developed skills for using measurement, will plan to measure something that is measurable, with the equipment and instruments available.

To enable learners to learn the measuring skill, it is important that the biology teacher uses graded exercises where learners start by using simpler measuring instruments, such as the ruler, thermometer, measuring cylinder and others and then later use more complex measuring instruments (Cavendish *et al.* 1990:27). Being able to measure accurately, indicates learners' ability to use the measuring skill. To ensure that learners develop the measuring skill, learners should double check and make sure they have measured correctly each time.

According to Cavendish *et al.*(1990:27) a learner who has developed the skill to measure, will always plan to measure an object that is measurable with equipment and instruments available. For example, various measurements can be taken of a pumpkin. The biology teacher obtains a number of pumpkins and divides the class into groups of four to six learners, and instructs them to take the following measurements:

Weight: Learners then use a bathroom scale or any available scale to determine the weight of the pumpkin. It is important that they weigh the pumpkin accurately.

Circumference: Wrap a non-stretchable string around the fattest part of all the pumpkin, and then lay the string along a meterstick to determine the circumference.

Height: Lay a flat piece of cardboard over the top of the pumpkin and measure the distance from the base to the highest elevation of the cardboard 'hat'.

Number of ribs: Count the 'longitude lines' going around the pumpkin. Will there be an odd number or an even number?

Thickness of wall: After the pumpkin of each group has been gutted, and had the fruit extracted, learners make slices through the peel, and take several measurements of its thickness. Is the fruit of the pumpkin uniform or does it vary at the poles and its equator?

Number of seeds: Extract the seeds, wash them and let them dry. How many seeds does the pumpkin have? Plant the seeds and wait for the seeds to grow to maturity. (It will take about four months to produce a mature fruit).

One of the most important benefits of the activity is that it goes beyond the concept of simple measurement. This example can also encourage curiosity in the minds of learners, meaning that the next time they eat at the dinner table, they will be curious enough to wonder about the food in front of them. 'How many seeds are in a tomato?' 'How thick is an eggshell?' 'What proportion of an orange's mass is peel?' (Leyden 1989:34-35).

By measuring components of different organisms, objects, and events, the biologist acquires quantitative data which can be dealt with graphically and statistically (Schilling *et al.* 1990:26; Van Aswegen *et al.* 1993:16 and Zeitler & Barafuldi 1988:97). Quantitative data are therefore based upon measurements using measuring devices correctly and with required accuracy.

(f) Prediction

Prediction refers to a cognitive process that requires one's best guess based on the information available (Funk *et al.* 1985:25 and Martin *et al.*1997:13). Hester (1994:119) describes prediction as the speculation of what might happen in the future.

Prediction incorporates careful observation and the inferences drawn about the relationship between observed events (Van Aswegen *et al.*1993:33). For example, the biology teacher could ask learners what will happen if a flame is brought close to a peanut. Most learners will predict that it will be scorched and turn black, but it actually lights up and burns, because of the energy stored in the oil it contains.

In the biology classroom the learner should learn to make predictions from very simple sets of data and from graphs, and as their predicting skills develop, they can make predictions on the basis of opinion surveys and other sources of information.

When practising the process 'prediction', the biology teacher emphasises the conceptual development of biology as a subject, implying that context should not be absent (Mossom 1989:226). The ability of learners to observe and predict, depends on the instruction they receive along with the knowledge they acquire by means of instruction (Van Aswegen *et al.*1993:33). This ability enables learners to interpret events and experiences, which will then reveal their understanding of situations.

(g) Using numbers

Learners need numbers to manipulate measurements, to order objects, and to classify objects (Smith & Welliver 1990:734). Although activities where numbers are learned depend largely on the mathematics programme in the school, the ability to learn numbers is also a basic and fundamental process of biology education. Learners use numbers in ordering, counting, adding, multiplying, dividing, finding averages, and using decimals and powers of ten.

Table 3.1, for example, illustrates the results of a experiment where learners compare the growth of beans and mealies in three different soil types namely, sand, loam and clay.

Table 3.1 An example of using numbers as a skill: The effect of different soil types on the growth of beans and mealies

	BEANS			MEALIES		
DAY	SAND	LOAM	CLAY	SAND	LOAM	CLAY
Day 10	2,4 cm	4,7 cm	5,6 cm	2,7 cm	3,8 cm	5,3 cm
Day 15	4,8 cm	7,9 cm	8,9 cm	4,0 cm	6,9 cm	9,2 cm
Day 20	6,9 cm	12,5 cm	14,7 cm	9,1 cm	10,4 cm	14,3 cm

During the experiment it was expected of learners to observe, measure plants in centimetres and use numbers to indicate the growth pattern of beans and mealies in the different soil types on day 10, 15 and 20. By using numbers learners can obtain information from which conclusions can be drawn. It is important that the biology teacher points out the value of using numbers for the learners to interpret information and show them how to do it beforehand.

The basic (simpler) biology process skills, as discussed on the preceding pages, can be considered as prerequisites for the integrated (higher cognitive) biology process skills.

3.4.3.2 Integrated biology process skills

Integrated process skills are dependent of the learner's ability to think on a high level and to consider more than one idea at the same time. The term 'integrated' implies that various of the basic process skills can be combined to solve problems. The basic process skills are prerequisites for integrated process skills (Martin *et al.* 1997:13 and Mossom 1989:74).

Integrated process skills are skills needed to execute scientific experiments. These skills consist of: defining operationally; interpreting data; controlling and manipulating variables; formulating a hypothesis and experimenting.

Padilla (1991:205-217) found a significant and strong relationship between formal cognitive abilities and integrated process skills. Integrated process skills deal with the setting up, conducting, and evaluation of experiments, and the formal thinking abilities of learners. Formal thinking abilities are the identifying and controlling of variables, while formal cognitive abilities deal with similar abilities.

As mentioned before, learners are not ready to cope with formal cognitive abilities and integrated process skills in the lower grades. It is therefore, advisable that these skills are developed in the higher grades.

(a) Defining operationally

According to Carin and Evans (1984:374) learners should learn to define terms in the context of their own experiences and work with a definition rather than to memorise it. This implies that when learners use the operational definition skill, they will use observations and other information gained through experience to describe or label an object or an event.

By using operational definitions, learners define terms in a context of their own experiences (Carin & Sund 1997:83). Thus learners work with a definition rather than memorising certain biology contexts. A definition that limits the number of things to be considered and that is experiential is more useful than a definition that encompasses all possible variations that might be encountered.

To enable them to communicate in the biology classroom by using terms that have a definite operational meaning, learners need to develop the skill to distinguish between definitions that are operational and those which are not (Cavendish *et al.* 1990:24). An operational definition will enable the learner to decide in advance whether it is worthy to continue with a particular investigation or not. For example the following statement can be investigated: Do plants grow quicker in sunlight? A further step is added: Do plants grow quicker in sunlight than in dark places? Here not only the variable to be observed (the growth of the plant) is specified, but the variable to be changed (the sunlight) is made explicit (Cavendish *et al.* 1990:24). The development of learners' thinking ability is aided by asking a particular kind of question which can be answered by the learners' own inquiry.

(b) Interpreting data

The process of interpreting data involves the making of predictions, drawings of inferences and formulating of hypotheses from the data collected in an investigation (Abruscato 1988:35 and Zeitler & Barufaldi 1988:97). To interpret data, learners need to collect observations and measurements (data) in an organised way and draw conclusions from the information (Van Aswegen *et al.* 1993:17). Learners should have had previous experience in making observations, classifications and measurements to be able to interpret data.

It is the essential task of the biology teacher to create these opportunities, such as interpreting data from different sources, tables and graphs. Results of an experiment could be set out in graphs which learners have to study to answer related questions. The graphs provide experimental data that learners should analyse and interpret to answer the questions.

Another example whereby learners could interpret data is by completing an investigation and then tabulating their results. For example, the biology teacher could provide learners with sheep lungs and a glass tube. Learners examine the lungs and determine the colour and texture of the lungs, distinguish the respiratory parts, and then observe what happens when air is blown through the glass tube (connected to the trachea), into the lungs. Learners can then work independently in groups of four and produce a table with data which they could then draw on the chalkboard for the rest of the class to analyse and interpret. Through this exercise, learners obtain the opportunity to evaluate data from several sources and then make their own interpretations. The ability to interpret data is fundamental; this indicates whether learners understand what they have observed.

Interpreting data includes the finding of patterns or associations within data, from which predictions (the drawing of conclusions) are made (Cavendish *et al.* 1990:27). Interpreting is concerned with relating one piece of data to another, from which data is gathered and organised (Van Aswegen *et al.* 1993:18). Interpretation of data also implies that data derived from an experiment can be used to make generalizations that are supported by the experimental findings.

(c) Controlling and manipulating variables

To determine which conditions make a difference in an experiment, learners are required to identify factors of an experiment that can affect its outcome and to keep these factors constant, while manipulating only the factors (variables) that are independent (Martin *et al.* 1997: 13-14). In any investigation, the best results are achieved when variables can be identified and carefully controlled (Abruscato 1988:34). By controlling a variable the condition of a variable can be managed.

To identify variables implies the recognition of the characteristics of objects that are constant, or that change under different conditions. Three important variables in biological investigations can be distinguished:

- *A controlled (fixed) variable*: It is a variable that is kept unchanged as this variable could affect the outcome of an experiment. Therefore, this variable is deliberately kept constant (Van Aswegen *et al.* 1993:13).

- *Manipulated variable (independent variable)*: The variable is deliberately changed or manipulated by the experimenter. The experimenter arranges conditions in some way or other which are independent of other conditions. Conditions are independent when they do not depend on the responding variable (Van Aswegen *et al.* 1993:13).

- *A responding variable (dependent variable):* A variable that changes during an investigation as the manipulated variable changes, is called a responding variable (Carin & Sund 1997:13). The responding variable is dependent, in the sense that it depends on the treatment it receives for example: water, light, temperature, food and others. The responding variable represents the outcome (effect) in response to the treatment (cause).

The learner changes or manipulates one variable in a systematic way. While doing this he/she watches and measures corresponding changes in another, or responding variable. At the same time, the learner holds all the other variables constant. By controlling a variable learners should be able to manage the condition of an investigation.

To develop the skill to control variables, opportunities should be created by the biology teacher where learners will develop the ability to identify, select and control variables when doing an experiment (Padilla 1991:206). For example, learners investigate the growth of beans that are planted under identical conditions. The bean plants are however, given various measured amounts of water. Learners have to observe the resulting difference in growth of the beans and at the same time determine the independent, dependent and controlled variables in this experiment.

- The amount of water (manipulated/independent variable) is under control of the experimenter, as she/he can decide what amount of water can be given to the plants.

- The resulting difference in growth (responding/dependent variable), depends on the amount of water. If the amount of water changes, the growth of the plant will change.

- Conditions such as the sunlight and soil should be held constant, during the experiment, in order not to have an effect on the outcome. Therefore the sunlight and soil are the controlled variables since they are deliberately held constant.

The development of the process skill to identify and control variables can be a difficult process to develop (Van Aswegen *et al.*1993:18). Progressive activities should however, be created where learners can practice to identify and control variables in an experiment. By doing so, the learners should eventually reach the level of development where they will be able to identify and control variables in experiments.

(d) Formulating a hypothesis

Collette (1973:6) interprets a hypothesis as the activity of the theorising about untested speculations in biology. Miller (1989:56) refers to a hypothesis as a proposed answer to a question or a possible explanation to information. Cavendish *et al.* (1990:25) defines the formulation of a hypothesis as the implementation of ideas that one has already gained from past experiences, in order to attempt to explain, or provide a reason for new content learned. A hypothesis can be used to guide experiments (Carin & Sund 1997:13). There seems to be as many definitions as there are authors, nevertheless, the most important function of the hypothesis is to determine what should be observed or tested, and what is to be expected as a result, thereby bringing order to an observation.

Formulating a hypothesis is therefore, the process of developing or identifying 'if' - 'then' statements on the basis of observations or inferences, which can be tested by conducting an experiment (Martin *et al.*1997:14; Miller 1989:56 and Mossom 1989:74). The following serves as an example, which can be used to practise the development of hypothesising skills: A class has been experimenting for several weeks with the growth and development of green plants. One of the learners observes that plants in the classroom move or bend towards the windows.

The learner infers that the green plants in the classroom move or bend toward the windows in response to light. On the basis of this information an observation can be inferred and formulated.

1. Do the stems of green plants grow towards a light source?
2. Do all stems bend towards windows?

Formulating a hypothesis

A hypothesis formulated on the basis of the first possibility above, would be that the stems of green plants grow towards a light source.

Predicting from the hypothesis

For this specific hypothesis, the presupposition would be: 'If stems prefer a light source to a dark source to grow in, then given a choice between these two conditions, they would choose a light source'.

The most important function of the formulation of a hypothesis is to explain the relationship between variables, to establish order in an experiment by determining what is tested, and what is expected as a result, and to give direction to a further research programme (Roth & Roychoudhury 1993:164). Through hypothesis-testing activities, learners acquire useful and practical information which stimulates their interest in relationships between existing variables.

(e) Experimentation

Experimentation can be described as doing something to discover what will happen (Abruscato 1988:37). When experimenting the learner changes objects or events to learn more about them. These objects or events are usually left unchanged when other process skills are used (Carin & Sund 1997:11 and Gega 1986:57). Experimenting can be described as the most sophisticated process incorporating all the basic- and integrated process skills discussed previously (Gega 1986:57). When a learner experiments he/she should be able to use some, or all, of these process skills.

Experimentation is not only the ultimate process skill, but is also the most complete as all the other process skills are utilized by the learner when experimenting.

Van Aswegen *et al.* (1993:89) divide experiments into three groups or categories:

Introductory experiments: These are short-term experiments performed by means of a demonstration. The demonstrations can also be used to illustrate how to handle apparatus or the techniques of carrying out an experiment.

Illustrative experiments: These are experiments carried out to confirm or illustrate some already known facts, concepts, or principles.

Investigative experiments: In this kind of experiment the results are not known beforehand, and are referred to as 'controlled' or 'true' experiments. The experiment is based on a problem about which new information is obtained under controlled conditions, and is designed to test a hypothesis that states a relationship between variables.

The function of the biology teacher during an illustrative experiment, differs considerably from his/her functions and activities during an investigative experiment. The learner is actively involved in the investigative experiment and is thinking while using different approaches and techniques.

When experimenting learners employ a sequence of steps, namely:

- stating a problem;
- formulating a testable hypothesis;
- identifying and controlling variables;
- measuring and observing;
- interpreting data;
- communication and
- inferring (Mhlongo 1997:186 and Mossom 1989:74).

These processes enable the learner to record the results of the experiment and to acquire the information needed to apply in other situations.

As mentioned earlier, process skills cannot develop in a vacuum, they need to be woven into appropriate content areas, and used in everyday situations. The importance of a process approach for both biology education and for everyday existence must be emphasised. A process approach is mainly learner-centred, and not only contributes to the development of learners, but has several advantages for biology teachers as well. It is important to emphasise the advantages of a process approach, since this can motivate biology teachers to implement the approach. In the next chapter the possible advantages and disadvantages of a process approach will be addressed.

3.5 SUMMARY

A process approach refers to a strategy which enables learners to develop intellectual skills to process information. Processes are the sequence of events which the biologist uses when performing a biological investigation. These processes can be divided in basic- and integrated skills.

Table 3.2 Basic biology process skills

Observation:	Using the senses to gather information about an object or event.
Inference:	Interpretation based on direct observations. Past experiences are generally used as a basis to make interpretations.
Classification:	The ability to order objects into groups on the basis of the characteristics.
Communication:	Different communication modes (oral, verbal and non-verbal) can be used.
Measurement:	Using appropriate measuring instruments to compare and order objects.
Prediction:	Determining or anticipating events based upon past observations and experiences.
Using numbers:	Use numbers to manipulate measurement, to order and classify objects.

Table 3.3 Integrated biology process skills

Defining operationally:	Defining of objects or events on the basis of their observable characteristics, when planning and conducting an experiment.
Interpreting data:	Using various forms of data to determine the validity of a hypothesis.
Controlling and manipulating variables:	Identifying the manipulated variables, responding variables and variables held constant, when conducting an experiment
Formulating a hypothesis:	The process of developing and/or identifying statements which can be tested by conducting an experiment.
Experimenting:	Verifying the hypothesis by using materials and controlling variables.

Basic- and integrated skills can be described as attributes of a continuum of science process skills, ranging from observation, the most basic skill, to the most complex skill, namely experimenting.

- A process approach, which is mainly learner-centred, not only contributes to the development of learners, but also has several advantages for the biology teacher. It is important to emphasise the advantages, since these could motivate and encourage teachers to implement a process approach successfully in the biology classroom.

In the next chapter the possible advantages, disadvantages and the benefit of a process approach when using *Curriculum 2005* will be discussed.

CHAPTER FOUR

IMPLEMENTING A PROCESS APPROACH

4.1 INTRODUCTION

In Chapter Two the possible impediments that may affect the implementation of a process approach, were indicated. To encourage biology teachers to implement a process approach when teaching biology, the possible advantages of this approach for the learner, the teacher and the new education system (as advocated by *Curriculum 2005*) will be discussed in this chapter. The criticism against a process approach and reasons why biology teachers may not use such an approach, will also be addressed.

The last part of this chapter will describe teachers' feelings; knowledge of such an approach; their views; the learners involved and the requirements necessary to implement a process approach. Different methods that can be used to assist biology teachers to implement changes will also be indicated.

4.2 ADVANTAGES OF A PROCESS APPROACH FOR THE BIOLOGY LEARNER

Arena (1996:35) and Mossom (1989:149) state that a process approach provides the learner with both the will and the skill for a lifetime of achievement and learning. By implementing a process approach in the biology classroom, the teacher and learner can experience both educational and real-life benefits. The following advantages of a process approach can be identified.

4.2.1 Active learner involvement

Generally the traditional teaching methods allow only a small percentage of learners to be involved in classroom discussions (McIntosh 1995:17). However, with a process approach group work is encouraged and learners are given the opportunity to investigate the environment on their own or with available resources and good classroom management (Preethlall 1996:142). Group work, based on inquiry activities, ensures that all learners are actively involved.

By actively participating in biology inquiry activities, learners acquire ways of investigating that enable them to make decisions from what they observe (Du Toit 1994:26 and Jakupcak, Rushton, Jakupcak & Lundt 1996:41-46). The ability to investigate and to make decisions, provides a foundation for a strategy that a learner can use when he/she encounters problems in everyday life.

Active involvement in inquiry activities also enables learners to recognise the tentativeness of ideas and to be flexible to change to new ideas (Jakupcak *et al.* 1996:43 and Watson 1990:48). The concepts that learners form to help their understanding of the world around them, changes as experience adds more evidence that may support or contradict a previous understanding. As learners become older and their ideas closer to those of adults, they change less often (Harlen 1993:76). Furthermore, the involvement of the learner in a process approach where material activities are used, tends to free the learner from the traditional rewards and punishment environment (Fleer & Hardy 1997:15-17). The learner becomes the marker of rewards for herself/himself.

4.2.2 Learners work co-operatively

A process approach motivates learners irrespective of abilities, race, sex or nationality to work together (Carin & Sund 1997:51; Parker 1985:44-46 and Slavin 1987:53-63). Hickman and Kennedy (1989:741); Sapon-Shevin (1998:15-16) and Watson (1991:141) argue that by working co-operatively learners' dependence on the biology teacher might decrease and at the same time learners' responsibility for their own learning might increase depending on the methods that the teacher uses.

In a sense, co-operative learning supports the construction of individual knowledge in a number of ways. As members of a group are required to explain or defend their viewpoint, learners will more likely construct a deeper understanding because they will need to evaluate, integrate and elaborate their existing knowledge (Brown, Collins & Duguid 1989:40; Hatano & Inagaki 1987:76; Kempa & Ayob 1991:341-354 and Roth & Roychoudhury 1993:127). When using a process approach, group work and self-assessment motivate learners to become involved contributors in the processes affecting their own educational progression and that of their peers.

Co-operative learning empowers learners by making them responsible for the acquisition of information to solve problems and complete specific tasks.

4.2.3 Development of communication skills

A process approach provides a means of overcoming the possible language barriers that may arise when traditional teaching approaches are used particularly in the multi-cultural schools in South Africa. According to a study conducted by Germann (1991:243-247) on Grade 9 and 10 biology learners in New England, language had no significant direct effects on the development of learners' process skills. According to this research finding the researcher is of the opinion that language differences in a class might not affect the implementation of a process approach. Limited English proficient learners can communicate where possible in their native language when involved in group work.

Group work involving inquiry activities enables learners to communicate ideas and findings at all levels (Arena 1996:36 and Ruiz-Primo & Shavelson 1996:1045-1063). As learners are free to communicate in the biology classroom during investigations, learners learn to communicate effectively in a variety of situations and to a range of audiences. When learners obtain, present and respond to information, they are actively improving their communication skills (Parker 1985:53 and Schneider & Lumpe 1996:87). Working in groups encourages learners to obtain ideas from one another by communicating, recording, writing and copying one another's experiments during investigations (Anastasiou 1996:51; Higher Education Quality Council 1998:1-2 and McIntosh 1995:17). Projects based on a process approach enable the learner to complete a task, by communicating biology knowledge to other learners.

4.2.4 Development of higher order process skills

A process approach, where open-ended inquiry activities are used, results in the development of higher order process skills (Hickman & Kennedy 1989:742). These include identifying variables, interpreting data, hypothesising, defining and experimenting (Schneider & Lumpe 1996:81-82). Inquiry activities permit learners to pursue questions of their own interest within given content areas and to seek answers to these questions by planning and designing experiments, by collecting the data, and by transforming and interpreting the data (Arena 1996:36 and Berge 1990:747). In this context the skills seem to develop holistically without being taught explicitly.

4.2.5 Mastery of knowledge

Huang (1991:26) and Yager and Huang (1994:98) are of the opinion that learners who experience a process approach as a model of instruction, display superior mastery of biology knowledge and biological processes, compared with those who experience the traditional textbook/lecture method.

Learning through a process approach may enable some learners to recall information faster than teaching biology by means of traditional teaching methods. Learners who have been more involved in their learning and its organisation, are better able to recall what they have learnt for use in other situations (Brotherton & Preece 1996:65-74). Learners make better use of the information they have obtained by experience and manipulation of objects than of the information that has been provided.

Furthermore, these learners also achieve better in terms of applications, creative ability, questioning, suggesting causes, and predicting consequences relative to a given situation (Adams & Callahan 1995:14-19 and Leonard *et al.*1991:400). When using process skills learners learn to think critically and apply their knowledge to solve problems rather than merely memorising facts.

4.2.6 Intellectual and personal growth at own pace

An enduring ideal of education is that every learner should proceed according to his/her own abilities (Gotfried, Hoots, Creek, Tampari, Lord & Sines 1993:340 and Harlen 1993:111). By providing inquiry activities for learners that enable them to think as biologists and make mistakes, biology teachers are creating opportunities for intellectual and personal growth that learners will not acquire in any other way (Dyfed 1992:57; Leonard *et al.*1991:400 and Qin & Simon 1990:281). Through such experiences where process skills are developed, learners will also be able to build on, refine and extend their ideas on biology knowledge.

A process approach can provide learning experiences which are designed so that learners can proceed at their own pace. Learners are responsible for their own learning and progress. Constant feedback and the motivation of the biology teacher enable the learners to produce their best work (Du Toit 1994:6-8).

4.2.7 Stimulating learners' curiosity

Learners who pay particular attention to an object or event and spontaneously wish to learn more about it by asking questions, are being curious (Harlen 1993:74). A process approach enables learners to use several senses to explore organisms and materials, ask questions about objects and events, showing interest in the outcomes of experiments

(Carin & Sund 1997:14 and Gega 1994:97). By means of a process approach learners are driven by curiosity and an urge to know and understand the world.

4.2.8 Creativity and inventiveness

Preethlall (1996:146) and Wilkinson, Dennis and Strauss (1995:146-147) claim that the present biology education system seems to bombard learners with a broad spectrum of knowledge that they have to master for examination purposes. The well-defined objectives of formal education prevent creativity and inquiry in formative thinking minds (Fleer & Hardy 1997:15-17). Using a process approach encourages learners to be creative and inventive when solving problems. To solve a problem through a process approach is generally a slow process, therefore, there is time for creativity and inventiveness, without being penalised (Lally 1994:7-12).

Learners who generate new ideas are being inventive. By using a process approach some of the learners might exhibit original thinking in their interpretations. They exhibit their inventiveness through verbal statements or actions or by using equipment in unusual and constructive ways, suggesting new experiments, and describing novel conclusions from their observations.

4.2.9 Development of critical thinking skills

Learners who can provide sound reasons for their suggestions, conclusions and predictions are thinking critically (Gega 1994:97). Learners that are able to think critically will weigh up the evidence and judge the validity of claims made, allowing them to reject those which may be biased or faulty (Adams & Callahan 1995:14-19). Biologists cannot always be regarded as unbiased or objective, therefore, it is important that learners reconsider and evaluate biologists' claims before they accept these as worthy information (Sanders & Doidge 1995:134 and Zohar & Tamir 1993:136-140). It is important that learners will develop critical thinking skills that will enable them to evaluate data critically before consuming biological information.

Inquiry activities enable learners to use process skills to justify evidence when drawing conclusions, predicting the outcome of untried experiments, justify their predictions in terms of past experience, changing their ideas in response to evidence or logical reasons, or pointing out contradictions in reports by their classmates (Schneider & Lumpe 1996:81-88). Critical thinking skills can only develop when explicit and deliberate efforts are made to practice and develop these skills (Resnick 1987:61). Lawrence and Lawson (1986:519) and Schymansky (1984:54) determined that the most effective approach to enhance critical thinking skills is through a process approach as learners use processes and thinking skills to acquire and apply information.

With the aid of a process approach, learners become partners in the progress of their own development. In addition, interest is stimulated and maintained throughout the biology curriculum. Learners acquire knowledge through inquiry activities and are able to apply the knowledge responsibly and ethically to situations outside the classroom. A process approach enables the biology teacher to combine theory and practice, which valuably influence learners observations, thinking and judgements.

4.3 ADVANTAGES OF A PROCESS APPROACH FOR THE BIOLOGY TEACHER

The benefits of a process approach for biology teachers, are no less impressive. Working with learners to develop their process skills can be an enjoyable experience as the approach refreshes the teaching of biology. The following advantages can contribute to this experience.

4.3.1 The teacher's role as guide/facilitator

In an inquiry centred programme where a process approach is used, the role of the teacher in the biology classroom changes drastically from his/her role in a traditional programme. He/she becomes a consultant to the learners (Malan 1997:6 and Watson 1991:141-144). Learners are at the centre of things, and the biology teacher is the facilitator, constantly using group work and teamwork (Hickman & Kennedy 1989:742). The learners communicate their observations and ideas to the teacher, who offers guidance to further stimulate the learners (Jakupcak *et al.* 1996:43 and Powell 1987:218). The learners ask questions about the materials presented and when the materials fail to produce satisfactory answers, the learners consult the biology teacher for guidance to help solve the problem.

Under such conditions a feeling of mutual confidence and respect may develop between teachers and learners (Watson 1991:141). When learners are able to make their own observations and form conclusions based on observations, the pressure on the teacher is greatly alleviated. The biology teacher is now free to concentrate on other issues, such as learner assessment. By using inquiry centred activities learners become effective investigators who are expected to think for themselves whether they had conclusively proved their point or not.

4.3.2 The opportunity to link and apply biology content to life situations

Biology education has been compartmentalised for a long time. Each topic is treated as a separate entity. Very little, or no effort, is made to create links between topics (Van Vollenstee 1997:4). To add to this dilemma, practical work is usually done separately from theory (De Beer 1996:26 and Hurd, Bybee, Kahle & Yager 1980:388). A process approach provides an ideal vehicle to foster a kind of holistic biology education (Harlen 1993:135). However, this will not happen automatically and the teacher's willingness and ability to do so will play an important role. A process approach may enable the biology teacher to integrate practice and theory when teaching biology. The one without the other is out of context (Schilling *et al.* 1990:4 and Wellington 1994:30). The teacher can provide inquiry opportunities where learners use process skills during practical activities to acquire the knowledge learners need to make decisions and to solve problems. Biology teachers should link and apply biology content to everyday situations (Souter 1991:11-14). This linking of the biology content situations might have a positive impact on the learner's interest in biology and at the same time, provide him/her with practise to develop process and thinking skills. Furthermore, these skills can be practised and applied in-depth, in other subjects.

4.3.3 The opportunity to identify the interest of learners

The discussions that biology teachers have with groups of learners, contribute to the preparation of entire intra-class discussions (Harlen 1993:133 and Lee 1993:625-636). By participating in the discussions of each group and by listening, the biology teacher can pick up the points of interest and concern as well as novel ideas and problems, which could be investigated further.

4.3.4 Assessment of learner skills

The assessment of process skills is not as demanding as it seems at first. According to Harlen (1993:11) and Lee (1993:625-636) the monitoring of ideas does not require formal assessment, but can take place during the usual teacher-learner interaction. Learners are not only involved in the setting of their learning outcomes to develop process skills in the biology classroom, but also in the assessment of their achievement. Learners are encouraged to take more responsibility for future learning than merely relying on the biology teacher (Preethlall 1996:142). By using process skills to acquire knowledge, a wide variety of skills can continuously be assessed. Furthermore, assessment of process skills lends itself to group assessment and thus encourages co-operative and collaborative learning, as well as peer tutoring. Assessment strategies other than pencil and paper tests, are used when assessing process skills.

A process approach changes the focus from the consumption of knowledge to the construction of knowledge. The stress level to finish a certain amount of content for the final examination is also reduced. Biology teachers can finally optimise their role in shaping our country's future, by adapting a positive attitude and creating the climate and conditions which will bring about a successful outcome.

With abovementioned advantages concerning a process approach in mind this approach may be used to benefit the new South African education system, as advocated by *Curriculum 2005*.

4.4 A PROCESS APPROACH AND *CURRICULUM 2005*

Curriculum 2005 which should have been implemented in all South African schools in some grades by 1998, (National Commission on Special Needs in Education and Training 1997:15) is based on outcomes-based policy and principles (Gauteng Education Department 1997:4). Outcomes-Based Education can be defined as '...an approach that requires teachers and learners to focus their attention and efforts on the desired end results of education.' (Spady 1992:67). The term Outcomes-Based Education (OBE) has, as its starting point, the intended outputs (significant exit outcomes) as opposed to the inputs of traditional curriculum-driven education (Spady 1992:72). The outcomes of OBE are thus designed to produce an educational product (a learner) who will function appropriately in future. This is the key to OBE.

The most important feature of the *Curriculum 2005* is based on the belief that all learners can learn and achieve certain results (NQF 1996:27). It is this desire to have learners succeed that determines what content is presented to learners, what learning experiences are made available to them, how they are tested, how long they engage in learning particular knowledge or skills, and above all, what is valued in the educational process. The traditional concern for instructional time is replaced with a concern for learner centred learning. All instructional efforts are directed towards helping learners to achieve significant learner outcomes (Brandt 1994:24-28; Killen 1996:1-5; Landsberg & Burden 1998:32-35; Marzano 1995:44 and Smith 1991:52-55). The word 'outcomes' is used broadly as an inclusive term, referring to everything learnt, including social and personal skills, learning how to learn, concepts, methodologies, values, attitudes and including both intended and unintended outcomes (Spady 1992:67-72). These outcomes are the end products of a learning process.

All biology teachers at secondary and tertiary level are directly influenced by the shift to OBE as proposed by *Curriculum 2005* as it not only affects what is taught, but also how it is taught to enable all learners to learn (Van der Horst & McDonald 1998:18). The focus of the new curriculum shifts from content and the memorisation of statistics and facts, to the development of an inquiring spirit, leading to the acquisition of knowledge, together with the skills and attitudes to apply this knowledge in a constructive way.

Both a process approach (vide 3.4) and *Curriculum 2005* focus on the content and processes that guide the learners to reach the required end results. Content (what is learned) and process (how it can be learned) are both essential ingredients of the learning programme. Content will no longer be presented as the 'only' truth, but should be dealt with from multiple perspectives (Van der Horst & McDonald 1998:18). This does not imply that basic content falls away. On the contrary, learners are required to access content and to approach content from a critical stance. Therefore, it is important that learners develop critical thinking and problem-solving skills.

Curriculum 2005 and, to a greater extent, a process approach (vide 3.4) require from the biology teacher to place more emphasis on the development of skills and values, than on the mere acquisition of knowledge (Spady 1998:1). To ensure that learners gain the skills, knowledge and values that will allow them to contribute to their own success as well as the success of the community and the nation as a whole, critical outcomes (specification of what learners are able to do at the end of a learning experience) which underpin the Constitution, was adopted by the South African Qualifications Authority (SAQA) for *Curriculum 2005* (Government Gazette 1997:13). Critical cross-field outcomes are broad, generic and cross-curricular and state that all learners will do the following:

- Identify and solve problems in which responses display that responsible decisions using critical and creative thinking have been made.

- Work effectively with others as a member of a team, group, organisation, community.

- Organise and manage oneself and one's activities responsibly and effectively.

- Collect, analyse, organise and critically evaluate information.

- Communicate effectively using visual, mathematical and/ or language skills in the modes of oral and/or written presentation.

- Use science and technology effectively and critically, showing responsibility towards the environment and health of others.

- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

The above mentioned critical outcomes for *Curriculum 2005* coincide largely with the outcomes for biology education which learners should reach if a process approach is used.

The following outcomes for a process approach should be reached:

- Develop a sensitivity and cognition for the complexity and the relationship between problems of the community and the role that science plays in the solving of these problems.

- Work co-operatively and be actively involved in learning activities.

- Develop process- and critical thinking skills to acquire, analyse, and evaluate information in order to promote life-long learning.

- Communicate ideas orally and in writing.

- Show respect for life and the surrounding environment when making critical decisions.

- Understand the fundamental principals on how the global world works and develop an inquiring mind and a scientific approach to solve problems.

These outcomes for a process approach in biology education were compiled from work delivered by: Borman and Cooney (1986:25); Bybee and DeBoer (1994:357-358); Bybee and Uno (1994:557); Davis (1986:257); De Beer (1995:14); Dowdeswell (1981:5); Flannery (1989:48); Harbour (1993:92); Isaac (1990:54); Jenkins (1989:18); Jessup (1991-26-30); National Research Council Committee (1990:47); Samuels (1995:50-63); Tudge (1988:71); Van Aswegen *et al.* (1993:15-17); Van Rooyen (1988:43); Van Vollenstee (1997:63-70); Wardle (1985:26-28); Wedman and Kueter (1983:327-328) and Wellington (1989:9) and from interviews held with Killen (1998:*pers. comm.*).

In conclusion from the association drawn above between the critical outcomes for *Curriculum 2005* and the outcomes for a process approach, it seems as if a process approach and *Curriculum 2005* are both formulated to enable learners to develop skills that will enable them: to identify and solve problems; work co-operatively and communicate their ideas with others; acquire and apply information; understand the interactions of science, technology and the society and show the necessary respect and sensitivity for life and the surrounding environment when making critical decisions.

In addition to learners being able to demonstrate competence in the afore mentioned critical-outcomes of *Curriculum 2005*, SAQA (Government Gazette 1997:13-14) recommends that all *Curriculum 2005* programmes of learning and all teaching and learning practices be underpinned by the intention of making learners aware of the importance of:

- Reflecting on and exploring a variety of strategies to learn effectively.
- Participating as responsible citizens in the life of local, national and global communities.
- Being culturally and aesthetically sensitive across a range of social contexts.
- Exploring education and career opportunities.
- Developing entrepreneurial abilities.

Above mentioned additional guidelines of *Curriculum 2005* are reflected in the science process skills underpinning the syntactical structure of the natural sciences. By implementing a process approach in biology, a variety of strategies can be used (which will be discussed in Chapter Four) that contribute to the personal development of each learner and the social and economic development of society at large. By using a problem-solving strategy and engaging learners in inquiry activities, learners are actively participating in the classroom (Arena 1996:36 and O'Neill 1994:57-59). Through active participation learners develop process skills which enable them to become responsible citizens and culturally and aesthetically sensitive to a range of social contexts as they have to find solutions to solve problems in local and in global communities, by using these skills which they have developed (James & Kurtz 1985:62, Reconstruction and Development Programme 1994:96 and Watson 1990:49).

According to SAQA (Government Gazette 1997:15) eight areas of learning (within which the necessary knowledge skills and attitudes have to be developed/acquired) were identified for *Curriculum 2005* (Table 4.1). Every learning area presupposes specific skills, knowledge and attitudes (specific outcomes) that learners need to acquire in order to be allowed to progress to the next phase of learning. These specific outcomes are the building blocks which enable learners to achieve overall competence in a field at a given level and can be considered as the key to learning progression (NQF 1996:26). Specific outcomes are derived from the critical outcomes. The critical outcomes are of key importance as a focus for both standard setting and curriculum development, and should permeate specific outcomes at every level of the NQF (NQF 1996:26). The critical outcomes can be considered as broad statements of intent and of the learning activities that give direction to the statement of more specific guidelines for more specific outcomes (Van der Horst & McDonald 1998:20). Table 4.1 contains examples of specific outcomes for different areas of learning.

Table 4.1 Examples of specific outcomes for learning areas in Curriculum 2005 (Government Gazette 1997:15-16).

LEARNING AREAS	SPECIFIC OUTCOMES
Languages, literacy and communication	Learners must show a critical awareness of language usage.
Human and social sciences	Learners must demonstrate a critical understanding of how South African society has changed and developed.
Technology	Learners must apply a range of technological knowledge and skills ethically and responsibly.
Mathematical literacy, mathematics and mathematical sciences	Learners must use mathematical language to communicate mathematical ideas, concepts, generalisations and thought processes.
Natural sciences	Learners must be able to apply scientific knowledge and skills in innovative ways.

LEARNING AREAS	SPECIFIC OUTCOMES
Arts and culture	Learners must reflect on and become skilled in art forms and cultural processes.
Economic and management sciences	Learners must demonstrate managerial expertise and administrative proficiency
Life orientation	Learners must understand and accept themselves as unique and worthwhile human beings.

The specific outcomes mentioned in Table 4.1 for different learning areas in *Curriculum 2005* can also be identified in a process approach. Specific outcomes can be reached by the learner when using certain process skills in the different learning areas. Examples of specific outcomes for different learning areas when using a process approach are illustrated in Table 4.2. This table was compiled by using the views of the Department of Education (1997b:6-10); and of various education specialists (Fourie, McFarlane, Fraser & Van Zyl [1993:11-16]; Germann [1991:243-247]; Martin *et al.* [1997:17-20]; Mhlongo [1997:181-187]; Mossom [1989:60-76]; Self, Self & Self [1989:159-160] and Van Aswegen *et al.* [1993:15-17]).

Table 4.2 Examples of specific outcomes when using various process skills in different learning areas

LEARNING AREA	EXAMPLES OF PROCESS SKILLS	SPECIFIC OUTCOMES
Languages, literacy and communication	Communication	Describe or make oral presentations of an event or procedure using appropriate scientific terms.
Human and social sciences	I. Inference	Realise that inferences based on observations are tentative and subject to change with new data.
	ii. Time/space relationships	Describe the response of an organism or a population to environmental changes.
	iii. Prediction	Predict changes in the global world (increasing population growth, food shortage etc.).
Technology	Measurement, using numbers and interpreting data	Use measurements, numbers and interpret graphs to acquire information that can be applied for technology purposes.
Mathematical literacy, mathematics and mathematical sciences	I. Interpreting data	Learners use experimental data to establish mathematical relationships among variables (the calculation and use of correlation coefficients, for example: the meaning of correlations of -0,75,-0,50, -0,1, 0,20, 0,50, 0,75 and others).
	ii Measurement	Use a variety of conventional and international units to quantify scientific phenomena and or/events (grams, centimetres, kilometres per hour, joules and tons).
	iii Using numbers	Construct, read and interpret information in symbolic form (graphs, tables, and charts). Use numbers, conversions and symbols (%, >, <, =, @).

LEARNING AREA	EXAMPLES OF PROCESS SKILLS	SPECIFIC OUTCOMES
Natural sciences	Experimentation	Use various process skills and critical thinking skills to acquire and apply information in order to solve problems.
Arts and culture	Observation	Creativeness and inventiveness is used to describe and draw an experiment or observable characteristics of an organism (size, shape, symmetry, colour, texture and appendages).
Economic and management	Experimentation	Use processes systematically and take the necessary safety precautions when conducting experiments.
Life orientation	Formulate a hypothesis	Learners form questions and hypotheses to explore the natural world, test their own ideas and propose solutions to problems.

The process skills and their specific outcomes mentioned in Table 4.2 are however, not the only process skills that can be used in the different learning areas. Only a few examples of process skills and the specific outcomes were described to indicate the relationship between a process approach and *Curriculum 2005*.

As in the case with *Curriculum 2005,* a process approach enables the biology teacher to integrate theoretical and practical learning within inquiry activities where learners use skills to acquire information, reason independently of concrete materials and experience, engage in open argument and accept multiple solutions to single problems. Thus learners are encouraged to develop process skills that will enable them to learn for life after school. Adequate time is provided to all learners to be successful.

The connections drawn between a process approach and *Curriculum 2005* indicate that a process approach is not only an important approach for biology education, but can also contribute to the successful implementation of *Curriculum 2005.*

Although *Curriculum 2005* seems promising for the new education system of South Africa it was revised in June 2000 to *Curriculum 21* in order to improve teachers' classroom practice.

4.5 *CURRICULUM 21*

In June 2000 Kader Asmal (Minister of Education in South Africa) accepted the review committee of *Curriculum 2005's,* recommendation that *Curriculum 2005* will be replaced by what is called a 'National Curriculum Statement' (*Curriculum 21*), which will entail clear-cut guidelines, in plain language on what skills and knowledge teachers have to teach each grade and when teachers have to test learners on what they know and what they can do (Chisholm 2000:6). The key proposals of *Curriculum 2005* namely the principle of OBE and child centred learning activities will remain. Technology and economic and management sciences will be left out for the time being as there are a shortage of teachers and a lack of resources. Only six learning areas will be used namely: language, mathematics, natural sciences, social sciences, arts and culture and life orientation.

The shortcomings of *Curriculum 2005* are based on the following:

- Lack of resources in schools.

- Teachers were not involved in large numbers in the development of *Curriculum 2005* and this may contribute to insecurity and initial lack of confidence.

- Redeployment and retrenchments of teachers demotivate teachers who remain in the system.

- Teachers did not have time to consider the effect of *Curriculum 2005* on classroom practice (to build on good practices that may already have been in place).

- Inadequate teacher training.

- Learning outcomes are not clearly stated as teachers do not always know what concepts, content and skills learners should learn.

- The incremental approach for implementation is based on time lines and not on the experience of teachers (teachers are thrown in at the deep end).

- Textbooks are unaffordable in many schools.

- The education budget does not provide transport to officials to enable them to provide adequate support to the teachers at their schools.

- Inadequately trained officials are used to support teachers while well-informed facilitators at universities, colleges and technikons are not used to aid the successful implementation of *Curriculum 2005* (Chisholm 2000:6; Kriel 2000:*pers. comm.* and Loubser 2000:*pers. comm.;* National Professional Teachers' Organisation of South Africa [NAPTOSA] 1999:1-8).

Curriculum 2005 can be considered as a drastic and rushed change in the education system and was not thoroughly planned to ensure successful implementation (Chisholm 2000:6). The success of a new approach not only requires a great deal of planning but also assistance to teachers so that they will be able to implement such an approach. New OBE text books for the Senior Phase include very innovative suggestions on how teachers can overcome this problem.

Yet a process approach, *Curriculum 2005* or *21* are valuable for the biology teacher and should be implemented with care. It is therefore important that the biology teacher carefully selects the relevant methods to develop the identified specific skills.

Notwithstanding the positive effects of a process approach on the learner, the teacher, and *Curriculum 2005*, this approach has several disadvantages.

4.6 DISADVANTAGES OF A PROCESS APPROACH

A process approach is no easy task for those involved in biology education (Williams 1984:177). It is therefore important to consider the possible reasons why teachers are not using a process approach. Many points of criticism can be raised against a process approach. Some of the main points of criticism are as follows:

(a) The implementation of a process approach is time consuming for both learners and biology teachers. Teachers with large classes have difficulty in finding time to deal individually with all learner-queries (Van Aswegen *et al.* 1993:18-19).

(b) Lack of material, information sources and apparatus hamper the use of a process approach (Jenkins & McDonald 1989:41-42 and Wellington 1989:10-11).

(c) Teachers may not be competent enough to implement a process approach, because of inadequate training (Woolnough 1990:6).

(d) If skills and processes learned in biology are never subsequently used or applied, learners are unlikely to retain them (Wellington 1989:12-13).

(e) The work load of the biology teacher increases as he/she needs to prepare more thoroughly, attend work shops to stay ahead and devote more time in correcting learners' written work (Gott & Mashiter 1990:57-58 and Miller 1989:50-51).

(f) According to Bell and Gilbert (1996:20) the lack of teacher development in biology education may influence the attitude of the teacher negatively when implementing a process approach, for example:

- Fear of losing control in the classroom

For some teachers controlling the classroom is important for their reputation amongst their colleagues as a teacher who has good classroom control. The use of a process approach may contribute to less or little teacher control as learners are more noisy and tend to move more around the classroom.

- Amount of teacher intervention

Less intervention may result in some teachers feeling that they are irresponsible and not doing their job.

- Covering the curriculum

Apple and Jungck (1992:25) are of the opinion that many teachers tend to 'cut corners' in order to do only what is essential to implement a new approach. Because of time constraints, teachers might tend to concentrate on quantity rather than quality to get through the curriculum. The reason for this might be that teachers are concerned that the 'pace' that learning is taking place might be slower when using a process approach than when traditional teaching approaches are used.

- Knowing the subject

Many biology teachers might feel insecure about their knowledge of the biology content in curricula. When using a process approach learners might ask unexpected questions which teachers might not always know the answer to.

- Meeting assessments requirements

If teachers are unable to meet the requirements for the pass rate of their subject, they might not be eager to implement a process approach. Teachers need to feel confident about new learning outcomes, such as teaching process skills and how to assess these skills.

- Respect of learners

For most teachers it is important to be professionally respected by learners. Using a process approach might develop negative feelings of some of the biology teachers as they may experience that learners are becoming more independent by using other resources rather than the teachers' knowledge to acquire information.

- Appraisal

A process approach might induce negative feelings in some biology teachers as the approach may not reflect the teacher's hard work and notes in learners' books.

To encourage some teachers to change their negative feelings towards the use of a process approach, they should be supported to grow professionally. McCarty (1993:42-46) suggests that biology teachers should be supported to feel...

- recognised as valued individuals, as people are willing to change if they feel valued;

- a willingness to take risks as change implies the possibility of both success and failure;

- that mentors are available that will provide collegial support and

- a sense of fun, as change seems to be easier when it can be viewed through and analysed with a sense of humor and with fun.

Changes requires a great deal of planning, assistance, organising and hard work. Only biology teachers who are willing to accept this challenge, will be successful in educating their learners to become better biology thinkers.

4.7 CHANGING TO A PROCESS APPROACH

According to Bell and Gilbert (1996:111-117) to change to a new approach teachers' feelings, knowledge of such an approach, their views, the learners involved and requirements needed to change, will all contribute to successful implementation.

(a) Teachers' feelings associated with changes

Changing to a process approach requires that positive and negative feelings of teachers, which may arise from changing to a new approach, should be acknowledged. For example, teachers may feel...

- excited, anxious and determined;
- lost at times, or inadequate, annoyed and frustrated;
- scared when working with the unknown and
- insecure when they do not feel confident if things do not work out when a new approach is implemented the first time (Bell & Gilbert 1996:111-117).

It is important that teachers will be able to deal with emotional issues, conflicts, uncertainties, pressure, anxieties and worries which may arise when changing to a new approach. Colleagues and other role players should support teachers to overcome possible negative feelings and try and make a difference. Negative feelings can be seen as part of the change process and cannot be ignored or avoided.

(b) Knowledge of a process approach

To implement the process approach it is important to increase the transferability of new knowledge and skills to the classroom, increase emphasis on practice, feedback and training and engage biology teachers in study groups where they can interpretate the opinions of colleagues and identify needs and short-comings when implementing a new approach Robertson (1992:56).

To promote change, teachers have to reflect on, clarify and discuss the meaning, advantages and the limitations of a process approach with other teachers, during sharing sessions. Knowing that other teachers are also experiencing negative as well as positive feelings may encourage teachers to implement changes, thus aid the change process. Teachers may not only gain from one another but can also be empowered by such activities.

(c) Views of teachers concerning changes

When implementing a new approach teachers may advocate different views concerning the changes and challenges in biology education, for example:

- Some may see changes as a challenge which might be stimulating and valuable for them, rather than a problem or a threat (Bell & Gilbert 1996:111-117).

- Some may see changes as tiring, unnecessary and not relevant to our South African school situation (possibly because of large classes)(Fraser 2000:*pers. comm.*).

Whatever teachers' views are concerning the implementation of a process approach, they need to be encouraged and supported to feel comfortable in their own minds to implement this approach.

(d) Learners and changes

A gradual change towards a process approach is a necessity as not only teachers but also learners have to adjust to these changes. Feedback from learners about changes can contribute in determining the pace of change. Not only does the teacher change his/her teaching methods but also the learner has to accept these learning activities (Bell & Gilbert 1996:111-117). To promote change learners need to be supported to deal with these changes. Changes can be facilitated if learners know what are expected of them (they need to know what is going on and what the outcome will be).

(e) Requirements needed to change to a process approach

Several requirements need to be met if teachers were to change their teaching methods and classroom activities. Teachers need to plan and visualise alternative methods in the classroom to minimise the risk of being a failure (Bell & Gilbert 1996:117). To change to a new approach teachers need to...

- be mentally prepared (know what to expect);
- know that they could maintain control in the classroom;
- know of someone else's success;
- change at a gradual pace that can be controlled and
- be able to decide when they would start using the new approach (Bell & Gilbert 1996:111-117).

The challenge will be to enable teachers to use these requirements.

Fraser (2000: *pers. comm.*); Hargreaves and Fullen (1992:1-20); Jackson (1992:63) and Thiessen (1992:82) assert that different methods can be used to assist the biology teacher to acquire the requirements necessary to implement a process approach, namely:

- Teachers should be advised on how to teach to ensure that learners will develop certain skills. This can be done in the form of tips or suggestions that experienced teachers exchange with colleagues during biology meetings where teachers of different regions are present, or by means of professional magazines, such as Spectrum, Instructor and others.

- Another way of assisting biology teachers is to improve the conditions under which they work. The following conditions can be included: reduction of the workload of biology teachers, allocation of more time for lesson planning and reduction of number of learners in the class.

- Teachers should gain more independence (be empowered) by allowing them to choose textbooks, schedule classes, establish the curriculum and oversee their own evaluation procedures.

- Teachers should be assisted with encouragement, support, sympathy, respect and in extreme cases, a form of therapy to handle the psychological stresses of their work when implementing a new approach.

- Teachers should search, try out and modify strategies (trial- and error) that best respond to the needs of their learners. Successful classroom experimentation with a process approach can be constructed by teachers as follows:

  - Each teacher determines his/her lesson plans, units, resources, desk arrangements and teaching aids.
  - Each teacher describes and comments on everyday experiences in the classroom.
  - Each teacher analyses his/her lesson through critical reviews (Jackson 1992:63).

Every biology teacher should initiate changes as to how teaching could enable learners to develop certain skills. Teachers can consider and experiment with different strategies and adopt those which improve the quality of the implementation of a process approach.

- Teachers can learn much from each other. According to Thiessen (1992:95) teacher development approaches which build on collegial and collaborative work among teachers have become important for school improvement and educational change. Examples are: peer coaching, co-operative professional development, advising teachers and mentoring. The following teacher-teacher approaches can be followed to exchange ideas concerning the implementation of a process approach, namely:

  - Two teachers combine their classes where one teacher is the 'expert' who organises the lesson activities while the other teacher is the 'assistant' learning from the 'expert' how the process approach should be implemented in the lesson.
  - Two or more teachers work together to plan the lesson. They pool strategies and resources, compare ideas, determine the process skills that learners should develop during the lesson and evaluate the success, merit and worth of their outcomes.
  - Teachers can communicate with one another by writing and exchanging memos of important classroom experiences (Thiessen 1992:95).

  Teachers can form partnerships with colleagues to change their classroom practices and generate and sustain the energy to keep up with changes. By monitoring each other, teachers can learn how to implement a process approach.

- It is also important that teachers and learners will be actively involved when determining, planning, adapting and evaluating a new approach. The following modes can be followed to enhance involvement of learners when implementing a process approach:

  - Teachers should involve their learners in decisions about the purposes, organisation, content, teaching methods and evaluation of learning.
  - Learners should not only become peer tutors for other learners but also join with teachers to understand what the approach is (Thiessen 1992:95).

To implement a new approach teachers need to be convinced that there is a need for change and be able to determine the direction of the change, before they would implement any changes. Changes cannot be successful if forced onto teachers.

4.8 SUMMARY

When implementing a process approach in the biology classroom, the teacher and learner can experience both educational and real-life benefits. Notwithstanding these advantages of a process approach, this approach has several disadvantages.

The importance of a process approach is stressed by indicating the resemblance between a process approach and *Curriculum 2005*. Critical- and specific outcomes of the eight learning areas as adopted by SAQA for *Curriculum 2005,* reveal major links with the outcomes of a process approach. *Curriculum 2005* indicated several shortcomings and had to be renewed by implementing *Curriculum 21* in order to improve 'classroom practice'. The eight learning areas of *Curriculum 2005* were reduced to six. The two learning areas that will be excluded are technology and economic and management sciences.

The success of such an approach requires a great deal of planning and recognition of the teachers' social, personal and professional development. Teachers should be encouraged to change their negative feelings towards the use of a process approach by supporting them in a professional manner.

To implement a process approach teachers' feelings, knowledge of such an approach, their views, learners involved and requirements needed to change may all contribute to the success of such a change. Furthermore, teachers should develop and be supported to change effectively. Teachers can try new strategies that may work the best on their own, learn from expert colleagues and involve learners when implementing a process approach.

Notwithstanding the changes, a process approach, *Curriculum 2005* or *21* enable the biology teacher to integrate theoretical and practical learning within inquiry activities where learners develop skills they need to learn for life. It is important to select inquiry methods that can best develop these skills.

In the next chapter the different strategies and methods needed to implement a process approach effectively, will be discussed.

CHAPTER FIVE

METHODS THAT CAN CONTRIBUTE TO THE IMPLEMENTATION OF A PROCESS APPROACH

5.1 INTRODUCTION

The main purpose of this chapter is to describe the different strategies and methods that can be used to enhance the development of process skills. This chapter therefore provides methods of inquiry which the biology teacher can use to develop basic- and integrated skills, that are important to implement a process approach successfully. Methods based on a problem-centred strategy, such as the cognitive question method; practical work methods, which include the laboratory, field work and worksheet method; the small group method and the project method, will be discussed.

5.2 DEVELOPING BIOLOGY LEARNERS' PROCESS SKILLS

Different researchers on a process approach present different theories on how process skills could be developed. Shield (1996:5) maintains that when learners enter school they are already able to use process skills which are in constant use, since these skills partly constitute brain activity. Learners need not be taught these abilities - they only need to practice them.

In contradiction to the above viewpoint, Strawitz and Malone (1987:53-60) aver that several studies in the past (Ashley & Butts 1972:96-116 and Butts & Raun 1969:3-8) have argued that process skills can actually be taught. Results have proven that learners who have developed process skills through instruction, retain them over a longer period of time. Even relatively brief process instruction can produce long-term retention.

Therefore, Strawitz and Malone (1987:53-60) advocate that explicit instructional procedures should be followed to develop process skills. Esler and Esler (1981:67), Finch (1989:174-175) and Tamir and Amir (1987:137-143) agree with Strawitz and Malone, that *formal instruction* is necessary to develop process skills in biology education. They also added that if 'process' is considered to be roughly equivalent to learner problem-solving or cognitive ability, then it is important that learners exercise it constantly.

Yeany, Yap and Padilla (1986:278-279) elaborate further, by arguing that if a process approach is to be child-centred, not only must the learners' interest and characteristics be taken into account, but also the cognitive structure of individuals. Process skills can be mastered if the learning activities are appropriately matched to the level of the learner.

Research findings of Mossom (1989) and Mhlongo (1997), obtained in South Africa, confirm that instruction has made a significant contribution to the performance of learners in all basic- and integrated skills. Basic- and integrated skills are not intuitive; they can be developed by means of explicit instruction, which can facilitate learners to develop and implement skills.

Furthermore, the possibility of developing process skills through instruction endorses that learners do not develop a skill as a result of merely a single exposure to it (Brotherton & Preece 1996:65-94). In addition to an explicit introduction to a skill, learners also need frequent practice in using the skill (Harper 1997:45 and Qin & Simon 1990:281). According to the Curriculum Frameworks for Science Technology and Mathematics (1995:12-13) classroom procedures should be interactive and investigative with co-operative learning as a feature of classroom practice to enable learners to develop process skills. Continuous practice in skills should be accompanied by instructive guidance from the biology teacher.

One way of providing learners with practice in these skills in the biology classroom, is to allow them to work on various types of inquiry activities, such as small-group work, practical laboratory work, field work, worksheets and others (Clackson & Wright 1992:39 and Roth &

Roychoudhury 1993:127). To improve the development of process skills in general, classroom activities should be designed in order for learners to practice these skills.

Since the major objective of the process-based approach is to facilitate the development of learners' process skills along with the discovery and continuous development of biology knowledge, it is important to use biology activities to acquire and apply this knowledge in their daily lives.

As mentioned earlier (vide 2.2.3.1), mere expository teaching activities fail to provide the opportunities for learners to develop a rational basis to apply biology knowledge in their own daily lives. The acquisition of biology knowledge will have little relevance for learners, unless it can be shown to have personal, social and economic applicatory value (Yager & Huang 1994:98). According to numerous writers (Chacko 1993:47; Clark & Starr 1986:243; Isaac 1990:65; Leonard 1991:84; Matlock 1995:167-168; Tobin *et al.* 1994:51 and Van Aswegen *et al.* 1993:75), expository teaching methods which merely concentrate on the teaching of content have been shown to be inadequate as a strategy for the development of process skills which learners need to learn for life. In order to develop learners' process skills, it is important to pay attention to the ways that process skills can be taught. For example, learners are often required to interpret data from graphs, tables and other graphic presentations, when writing tests and examinations, but they are rarely encouraged to construct such graphs and tables during their course work (Hudson & Reid 1988:159; Van Dyk 1986:201 and Yager, Tamir & Kellerman 1994:269). In the traditional textbook-lecture approach the focus of the lesson is on subject matter only, rather than on the development of relevant skills, since few opportunities exist for learners to hypothesise or to design and actually perform an experiment .

Goldberg (1982:10) states that: '... learning about science through active participation, however can bring so much more than just knowledge. By using skills of scientific investigations, children can learn the need to speak truthfully; to use language carefully; to cooperate with others; to be tolerant to others' views and to allow for mistakes and failure in others' work, as well as in their own, ...'

When teaching biology to develop learners' process skills, various strategies and instructional methods may be used, depending on the topic and on the grade, as well as on the particular development level of learners. Very often, the biology teacher will have to use a combination of several learning and teaching activities.

Before actually deciding on which strategies, methods and activities to use, the teacher should determine the outcomes of the particular lesson, as well as which process skills will be exercised. For the high school learner, the biology teacher should use exercises where learners can analyse and evaluate biology information and impart intelligently what they have learnt (Van Aswegen *et al.* 1993:74 and Druger & Vaidya 1996:10). Learners should be able to understand and apply the facts that they have learnt. This implies that the biology teacher will generally use a *combination* of strategies, methods and techniques to ensure that learners are actively involved in the asking of questions and the planning and carrying out of investigations and experiments. To a certain extent, the strategy and methods used, will also depend on the environment, the apparatus and material available (Hickman & Kennedy 1989:742 and Tamir 1986:51). When choosing a teaching method biology teachers should at all times take into account how learners can best understand the topic or theme.

A particular strategy which involves learners actively engaging in problem-solving activities can be used (Hester 1994:34; Lawrence & Lawson 1986:519 and Sanders 1993:10). These problem-solving activities require learners to use process skills and at the same time require them to think critically, before solving a problem (Hester 1994:34). Opportunities should be created where learners explore and investigate the world that surrounds them to find solutions for problems. Consequently it is important that the biology teacher should use a problem-solving strategy whenever he/she teaches biology.

5.3 PROBLEM-SOLVING AS AN INSTRUCTION STRATEGY TO DEVELOP PROCESS SKILLS

Averring that biology teachers need to prepare learners to solve problems seems obvious, yet in the traditional biology classroom, meaningful and transferable problem-solving instruction rarely takes place (Dekker 1996: *pers. comm.*). The textbook remains the primary teaching resource. In nearly all cases learners learn that there is only one right answer and only one specified correct way whereby to obtain it. Direct instruction and rote learning are inseparable components of current biology education (Brotherton & Preece 1996:65). In order to enhance the higher levels of thinking and problem-solving, basic concepts and ideas need to be explained, learned and remembered (Tamir 1986:51). For example, learners will not succeed in biology if they have not memorised the basic classes and phylums of plants and animals. However, most concepts and ideas that should be learned in biology may be more interesting, more easily applied and better remembered, if they are taught by means of a problem-centred approach where learners explore and discover for themselves.

5.3.1 Using a problem-centred approach in the biology classroom

When using the problem-solving strategy in the biology classroom, the teacher and learners investigate a problem and try to find solutions to solve the problem (Ost & Yager 1993:287). The learners then suggest possible ways in which the problem may be solved. Information is collected by means of experimentation and investigation in the laboratory, during field excursions or by means of research in the library (Jakupcak *et al.* 1996:41). In selecting the problem, the biology teacher should consider the age, stage of development and ability of learners. The degree of difficulty of the problem should be adapted to the learners' learning capacity (Koedel 1992:16). If the problem is too difficult, learners will become discouraged and if it is too easy, they will lose interest.

The availability of resources should also be considered when applying the problem-solving strategy. The teacher has to ensure that the relevant material and equipment are available to solve the problem (Yager *et al.* 1994:269). Since problem-solving is so complex and variable, it is important to divide the problem-solving strategy into smaller processes.

5.3.2 Different problem-solving processes

McIntosh (1995:16-18) divides problem-solving into four overlapping and interactive processes namely: posing of problems; approach to problems; problem-solving and communication.

- *Posing of problems*

Posing of problems implies that a problem is identified in a real situation (McIntosh 1995:16 and Slabbert 1997:80). For example, an experiment can be designed (modified and/or performed) where learners can: control variables; revise a hypothesis; make predictions; describe patterns; use models; apply experience and previously learned knowledge, as well as identify relevant information and describe how that information might be obtained.

- *Approaches to problems*

This step involves the evaluation of information and determining the relevance of the problem (Jungck 1985:264).

- *Problem-solving*

Learners should be able to suggest reasonable solutions to the problem that is posed (Jungck 1985:264).

- *Communication*

Learners are given the opportunity to communicate their procedures, interpretations and trajectories of thinking which were followed, as well as show the validity of conclusions, when they use and analyse data (Gayford 1989:193-195).

When planning the biology lesson it is imperative that the biology teacher should ensure that all learners will have an opportunity to practice each process of the problem-solving method (Hester 1994:139-151). The biology teacher should not only be looking for solutions to the problem, but constantly determine whether learners are able to apply the skills needed in each of the four processes described above.

5.3.3 The value of a problem-solving strategy

The problem-solving strategy involves a more heuristic approach where learners are given the opportunity to use and apply content and to discover for themselves (Fortner 1992:77 and Hester 1994:139). Learners who participate in problem-centred activities in biology will be learning to develop and apply thinking skills because they are expected to utilise their own resources and experiences when approaching new situations (Adams & Callahan 1995:14-19 and Germann 1991:243). Learners will learn to consider biology and the study of biology, as a meaningful activity and will be inherently motivated to learn biology.

Problem-centred teaching also enables learners to become task-oriented rather than performance-oriented, since the task-oriented teaching strategy demonstrates that learning can be fun and it enables learners to apply concepts and skills to situations outside of school (Gayford 1989:193-195).

Irrespective of the advantages of the problem-centred strategy, biology teachers do not always use this strategy. Several reasons are suggested for this.

5.3.4 Limitations of the problem-centred strategy

The reasons why biology teachers do not always use the problem-centred strategy, can be related to the following shortcomings of this strategy (Brady 1987:58-60; De Beer 1995:32; Gotfried *et al.*1993:340; Sanders & Doidge 1995:133; Schulze 1994:165-166 and Van Rooyen 1988:43-45):

- The problem-centred strategy is a long, drawn out and time consuming method. The lack of time frustrates biology teachers as they feel pressurised to cover content rather than using problem-centred strategies.

- The school or district does not always support biology teachers in instructional change.

- Biology teachers experience a lack of resources to create new lessons.

- Discipline problems are experienced when learners work in groups.

- Due to the lack of exposure to this strategy, most biology teachers fail to implement the problem-centred strategy successfully.

Implementing a new teaching strategy is a gradual process. It takes time for teachers and learners to feel comfortable with any new strategy and biology teachers should not feel compelled to incorporate a problem-centred approach into every lesson, right away (Hester 1994:143 and Moll & Allen 1982:95). Instead a transition process should take place during which teachers try one process such as posing of problems in one lesson and then how to approach the problem in another, until the entire problem-centred strategy has been covered. It is important though that the biology teacher selects instructional methods that will best develop problem-solving skills.

There is no single correct method to develop process skills, but there are many instructional methods that supplement one another. The ideal strategy to develop process skills in the biology lesson, therefore, very often consists of various instructional methods and learning activities (De

Beer 2000:*pers. comm.* and Van Aswegen *et al.* 1993:64). The success of the biology lesson depends to a great extent on how effectively the biology teacher is able to use the various methods of instruction. Therefore, the different instructional methods that can be used to develop process skills, are investigated.

5.4 INSTRUCTIONAL METHODS TO DEVELOP PROCESS SKILLS

A method can be described as a well-conceived (thought out) procedure, intended to achieve a specific aim (Fraser, Loubser & Van Rooy 1990:16). Instructional methods are used to engage learners with tasks designed to bring about meaningful learning and provide particular kinds of learning opportunities (Ellington 1987:10). A perception of instruction that knowledge is directly transferred from teacher to learner, does not fit the contemporary biology education situation. The learners' constructive mental activity should be considered. Instruction should provide experiences and information from which learners can develop new knowledge. To achieve the latter, it is important that when the biology teacher selects a method, the constraints in the classroom that might affect the feasibility of that particular method, be considered.

5.4.1 Selecting suitable instructional methods to develop process skills

Some of the constraints which might effect the selection of suitable methods are: the organisation of the timetable; staffing the school and the availability of resources such as transport for outside activities. These constraints can make it difficult to use methods that will involve learners actively (Ellington 1987:5). The biology teacher must consider whether the method he/she uses will help learners to develop specific process skills. Learners should have a clear view of exactly what practical skills will be developed (Fraser 2000:*pers. comm.*). The biology teacher also needs to consider whether the methods and learning experiences he/she provides will achieve all the outcomes he/she has in mind, furthermore, he/she should ensure that learners know what those outcomes are (Chisholm

2000:6). For example, many practical activities provide learners with opportunities to practise the complex process skills of working in a group, or to develop information-handling skills, but often these opportunities are insufficiently exploited. Only if the purposes of a lesson are perceived by the learners as being relevant to their needs, can the teacher be confident that the learners may effectively make use of such learning opportunities.

One cannot make any absolute statements concerning the matching of teaching methods to learning outcomes. Therefore, there is no single method that by itself can be adequate. Biology teachers should select methods which might best develop process skills according to their experience, professional expertise, and intuition.

According to Mossom (1989) Harper (1997) and Mhlongo (1997), the best methods that develop process skills are inquiry methods, where learners have to discover for themselves.

Some nations such as Israel and western Australia had success with inquiry methods when teaching biology because they carefully trained teachers in the subject matter and inquiry methods of teaching, and provided teachers with guidance and support (Walberg 1991:50).

5.4.2 Inquiry methods to develop process skills

The inquiry approach can be considered as a dimension of the progressive movement - as reaction against verbalism and formalism in biology education. It is in this inquiry approach where learners are given the opportunity to approach different problems actively by using different process skills (Carin & Sund 1997:83 and Germann 1989:236). Gagnè (1963:145) describes the inquiry approach as '...a set of activities characterised by a problem-solving approach in which each newly encountered phenomenon becomes a challenge for thinking...'. The inquiry approach can be described as a combination of processes that are designed to develop the thinking abilities and skills needed to confront a problem.

Other definitions include characterisation such as '...a search for truth or knowledge that requires thinking critically'; 'the process of investigating a problem'; 'making observations'; 'asking questions' and 'performing experiments' (Martin *et al.* 1997:18). When using an inquiry activity the biology teacher not only provides content, but also guides the learners cognitively and creates alternative inquiry opportunities, to ensure that learners explore relevant biology concepts (Fraser *et al.* 1990:3; Lötter & Slabbert 1993:38-40 and Van Dyk 1986:300-306). Learners should use certain process skills which would engender the skills of being able to make observations and to draw conclusions. They will be able to solve problems by means of the content which they have acquired. The processes which learners use in order to acquire information, should also enable them to solve future community problems (Lawrence & Lawson 1986:519 and Schymansky 1984:54). The inquiry approach is based on certain process and cognitive skills which learners use in order to acquire and apply information in everyday life situations.

The inquiry approach offers learners the opportunity to read, study, analyse and synthesise information from a variety of sources, from which they have to recall appropriate facts, concepts and solutions when drawing conclusions (Schneider & Lumpe 1996:81-88 and Tamir 1986:51). In order to be able to make informed decisions to solve a problem, it is important that learners should exercise their critical thinking skills. Critical thinking skills include: drawing of valid conclusions; isolation of variables; distinguishing between the findings of an experiment and conclusions made on the basis of the findings. These are all found in the processes of inquiry (Nisbett, Fong, Lehman & Cheng 1987:625).

According to certain scholars (Germann 1991:243 and Sydney-Smith & Treagust 1992:287), the major aim of providing inquiry activities, is to help learners develop problem-solving skills in a methodical manner, by using process skills. Learners should practice being biologists in order to fully understand the living world. Furthermore, they should learn that biology is more than a set of predetermined facts to be memorised. Biology is a process of inquiry that generates ideas and helps learners to construct and apply knowledge (Fortner 1992:77 and Mesmer 1996:31). Since there are many inquiry methods only those that may best develop process skills during biology teaching, will be discussed along with their limitations. From studies and recommendations of Harper (1997); Mossom (1989); Malan (1997) and Mhlongo (1997) on the development of learners' process skills, methods that might best work to develop process skills in the biology classroom have been selected. These methods are: the question method; practical work (which includes laboratory and field work); the project method and the small group (co-operative learning) method.

5.4.2.1 The question method

Although questions are important in every kind of lesson, questioning as a method of instruction refers to the organised way in which a series of carefully formulated questions are arranged around a specific topic before facts are taught about the topic (Van Aswegen *et al.* 1993:76). Questioning involves not merely a random selection of questions around a chosen topic, but a process which is carefully structured in two ways. On the one hand, it includes the preparation of key predetermined questions to guide the process and logical flow of conceptual development and, on the other hand, the spontaneous adaptation and accommodation of responses, both expected and unexpected, which are received from learners.

Questions are asked to actively involve learners in the learning process where they have to supply an answer. By posing questions to learners, they are guided to discover for themselves. Questions can be posed to the whole class, groups, pairs or on a one-to-one basis (Harper 1997:51).

Different types of questions can be used. Grossman's (1994:340) analyses and summary of the questioning style reveals the following basic framework and types of cognitive questions that can be used in the biology classroom.

(a) Focus questions and statements (closed questions)

Focus questions are used to direct the attention of the learners to specific aspects and relevant issues (Grossman 1994:340). Illustrations of this type of questions are: 'What is this?' 'What is this part of the sketch' 'What am I doing now?' Focus questions and statements are normally closed, in that they have only one correct answer.

(b) Higher cognitive questions

These questions are aimed to develop the cognitive thinking ability and insight; they allow for creative solutions and assist learners to construct meaning to new concepts. Examples of these types of questions are: 'What do you think about this?' 'What is happening here?' 'How does this compare to that?' 'Explain why this has happened?' (Collette & Chiapetta 1984:42).

The value of these questions is that opportunities are created where learners can express their opinions; decide on options; cogitate; formulate and expose understanding of new concepts (or a lack of it). These questions encourage learners to take risks whereby they generate many responses. The responses also encourage the development of a positive self-concept in learners. If the self-concept of learners and the content integrity of the lesson is to be encouraged and maintained, then dealing with incorrect responses to all types of questions asked, is of vital importance (Watson & Marshall 1995:291-299). The following suggestions represent some ways of handling inaccurate or incorrect answers: 'Please explain ....' 'I don't understand.' 'Can you run that through again?'; 'Rephrase the question.' Or 'Provide guiding clues, hints, cues or indications.'

(c) Summarising statements

These statements are used at various points in the lesson to summarise the intended content. The learners or teacher can complete summaries.

Statements could be: 'So what we have discovered up to this point is....' 'So to solve this problem you had to classify these substances....' It is therefore important to spend some time thinking about a problem before rushing into it (Harper 1997:52).

(d) Transfer questions

Transfer questions are mainly open questions and used to determine whether the learner understands the intended concepts. These intended concepts should be available to learners so that they can connect ideas to a general principle and be able to use and transfer knowledge to their own life experiences. Questions like the following fall within this category: 'Where else do you find....? Can you provide other examples?'

Convergent questions such as focus questions are used in order to build vocabulary for information background and to review and summarise. Open or divergent questions (such as transfer questions) and the summarising and understanding of higher cognitive questions are not restrictive and usually have more than one correct solution or answer to the problem. They should be thought-provoking and challenge learners to use their newly acquired knowledge in solving the problems with which they are confronted. Open questions are used to encourage creative thinking and discovery learning.

Although convergent questions make a valuable contribution to the development of process skills, too many questions asked by teachers may require only simple recall answers. A balance between focus and transfer questioning is desirable in order to determine learners' abilities.

5.4.2.2 Practical work methods

According to De Beer (1993:225) contemporary practical work is mostly executed according to recipe-like explicit instructions, with little emphasis on activities to promote discovery learning. Furthermore, most learners lose interest in practical work if it is not relevant to their needs and does not address the contemporary problems that learners have to face. Hodson (1990:33) elaborates by stating that 'practical work, as conducted in many schools, is ill-conceived, confused and unproductive. It provides little of real educational value. For many children, what goes on in the laboratory contributes little to their learning about science. Nor does it engage them in doing science, in any meaningful sense.' Whereas the role of a heuristic, problem-centred approach to practical work in motivating learners and in stimulating them to achieve affective and cognitive outcomes is well recognized, research done by De Beer (1993:225) shows that such an approach is seldom followed in South African schools. To develop process skills in the biology classroom the emphasis should shift to a more problem-centred approach based on community problems. By making use of laboratory and field work, learners should develop the skills they need to learn for life. When using practical work to develop process skills, the biology teacher should remember that practical work can never be isolated from theory (Moodley 1983:152 and Wilkinson *et al.* 1995:145). Therefore, clearly formulated outcomes for practical work are necessary for the successful development of process skills.

(a) Outcomes for practical work

To develop specific process skills and attitudes during practical work, O' Neill (1994:57) recommends that the following outcomes should be reached by the learners:

Laboratory skills:	Learners should learn to handle apparatus and chemicals carefully and correctly.
Scientific processes:	They should also learn to think logically and make accurate observations and predictions.
Social development:	Learners need to develop leadership, communication skills, and learn to work responsibly in groups.
Exploration:	Exploration and observation of facts should be a priority.

Problem-solving: Opportunities should be provided where learners can use their problem-solving skills.

Discipline: The biology teacher should aim for learners to work neatly when executing their tasks.

As mentioned in Chapter Four (vide 4.4) connections between above mentioned outcomes and the critical cross field outcomes of *Curriculum 2005* can be made.

Achievement of above outcomes will contribute to the acquisition of general aims of practical work in biology, which are: to increase learners' understanding of content; to develop a variety of skills and to make biology interesting and enjoyable. To enable the biology teacher to reach above mentioned aims when doing practical work, the laboratory and field work method can be used. These two methods are briefly discussed.

(b) Specific methods for practical work

(i) The laboratory method

The laboratory method can be described as a hands-on, minds-on approach to biology, in which the learners have the opportunity to gain some experience with the phenomena associated with their course of study. The laboratory method plays a vital role in the development of process skills when teaching biology, since learners acquire experience in a process approach through inquiry and discussion (Kernsillabuskomitee: Natuurwetenskappe 1994:20). The laboratory method enables learners to investigate, experiment, explore and acquire knowledge that can be applied to the problems which they may encounter in the future (Clackson & Wright 1992:41 and Goh *et al.*1989:430-432). Therefore, laboratory investigations should be explorative so that learners can explore facts and principles by means of materials, apparatus and instructions, in order to complete practical assignments (Fraser 1984:43). Practical assignments in the laboratory contribute successfully to a process approach, since learners use process skills such as observing, classifying, experimenting and other skills to find solutions to their problems (Garnett & O'Loughlin

1989:27). There are, however, both advantages and limitations in the laboratory approach. The following advantages are reiterated:

- Learners are provided with opportunities to view biology as it is practised, rather than merely reading or hearing about it.
- Learners experience 'hands-on' activities to understand certain concepts or events.
- Learners are able to observe with all their senses.
- Important skills, techniques and the handling of apparatus are improved.
- Learners are prepared as possible future biologists, since they gain first-hand experience in biology investigations. Well-designed worksheets can be used to promote learners' abilities to complete practical assignments successfully and to record their experimental findings in a meaningful and a logical way (Chacko 1993:47; De Beer 1993:57-68; Druger & Vaidya 1996:216 and Slabbert 1992:35-38).

Unfortunately, the above-mentioned values of laboratory work cannot always be guaranteed because of the contemporary approach and deficiencies in biology education that were discussed in Chapter Two.

Some disadvantages have been associated with the laboratory method. Research conducted by Clackson and Wright (1992:41) concerning the effectiveness of laboratory activities, indicated that laboratory activities are time-consuming and cannot always ensure the development of higher order process skills.

There are insufficient laboratory facilities in many South African schools due to financial constraints (De Beer & Van Rooyen 1990:54). To combat this financial problem, everyday objects can be used as apparatus. For example, 2 litre coke bottles could be used to illustrate the process of photosynthesis or for the making of a vivarium.

Irrespective of the disadvantages linked to the laboratory method, it can be considered as an indispensable method to develop process skills, to enable learners to explore on their own, acquire information, and solve problems. Work in the laboratory can be done in conjunction with field work, which should enable the biology teacher to teach biology in all its dimensions and manifestations.

(ii) Field work

Field work refers to work of an investigative and experimental nature in the environment. The environment includes any natural or man-made environment in and between buildings; in gardens and in the agricultural arena (Schulze 1994:166). The focus of field work is usually on ecology whereby learners are provided the opportunity to explore the living and non-living components of a particular environment.

Field work can also be used for environmental education. Observations and explorations made during field work create love, respect and a concern to conserve nature (Lehman & Schilke 1987:80). Since field work sometimes delivers unplanned and spontaneous situations, these situations could lead to an increased interest in the environment and motivate learners. Learners develop and apply process skills while they are investigating relevant problems in their environment (Opie 1995:106). Themes such as conservation, pollution and sustainable utilization enable the teacher to create opportunities during field work where learners can explore community resources (Fail 1995:524). For example, learners can regularly visit a dam or river near their homes in order to explore the problems that the community encounters with the utilization of this resource. Such an activity creates an opportunity where skills such as observing; communicating; inferring; predicting; formulating a hypothesis; defining operationally; interpreting data and controlling variables, can be practised and developed.

Learners could...

- identify and classify all the living organisms in the area;

- observe what these living organisms eat and do;

- design a food chain to illustrate the relationships between these organisms;

- determine how the humans use this area and how will it be used in future and

- formulate what they have learned from their environment and how this changes their views (Opie 1995:106).

Although field work is sometimes regarded as complicated, confusing, disrupting and time consuming, such excursions can be significant for both teachers as well as learners (Lehman & Schilke 1987:80). It is important that the biology teacher should plan field work thoroughly and to maintain learners' interest, ensure that all learners participate actively in explorative activities, investigations and discussions in order to provide possible solutions to the problems (Schulze 1994:166). Field work provides the opportunity for learners to be exposed to real life problems. It further enables learners to develop a certain perspective and dedication concerning community problems.

Explorative methods such as laboratory work and field work used in a process approach enable learners to develop process skills which they need in order to become successful learners. Laboratory and field work enable learners to develop the necessary process skills and techniques for practical investigations.

(c) Implementing the practical work method

De Beer (1995:26) researched the problem areas concerning practical work in South Africa and recommends the following to facilitate successful practical work:

- A problem-centred strategy should be used, where learners can develop the process skills they need to solve future problems.

- Practical work should be relevant to the learners' environment.

- Topics should be taught in relation to the environment in which learners are living.

- Since practical work is expensive and demands competent teachers, an alternative approach which could be followed, is a *minds-experiment.* This approach uses experiments, which have already been done by researchers, for class discussions. Time, methods and the results of experiments are explained in a simple way, after which learners receive opportunities to discuss the problem and to formulate a hypothesis. This can be an open discussion or can be based on structured questions or assignments (Papenfus 1995:58 and Wilkinson *et al.*1995:145). The minds-on approach can be used in schools that do not have laboratories. It is important that learners master skills such as investigating problems and exploring and finding solutions to problems even if facilities are inadequate.

Schools that do have laboratories, should use them to provide learners with the opportunities to develop the process skills they need while experimenting. Practical work can be seen as an opportunity where a problem could be posed to learners which they have to solve creatively by using different process skills. To encourage learners to explore and solve problems, it is important that the problems are relevant and challenging. Practical work can be viewed as a contemporary necessity, in order to find solutions for problems in real life. It encourages learners to explore and solve problems, but these should be relevant and challenging.

5.4.2.3 Small group method (co-operative learning)

Because of the importance of social interaction with peers and with more competent individuals as regards learning and intellectual development, the small group method (or co-operative learning) becomes an important method, to develop process skills (~~Kempa & Ayob 1991:341-344; Lord 1994:281; Slavin 1987:53 and Watson 1991:141~~). The small group method can be described as a group of learners collaborating to construct knowledge together (Shevin 1990:21-29). It is based on the positive

Piaget 1953; Vygotsky 1978 English translation
Donald, D. Lazarus, S. Lolwana, P. 2008:6

interdependencies of learners which involve the sharing of ideas; application of knowledge; using of skills; exercising of cognitive abilities and instilling a sense of responsibility (Druger & Vaidya 1996:27). When using this method, the biology teacher organises the class into small groups so that learners can learn to work co-operatively.

There are a variety of activities where the small group method can be used to develop learners' process skills, of which only a few will be discussed briefly.

- Inquiry group

The biology teacher presents an event, and asks learners to try and explain what has happened during the event. While working in the group, learners are allowed to ask questions and perform possible experiments in order to confirm their inferences or conclusions (Watson & Marshall 1995:291-299). For example, different pictures of soil erosion can be displayed, from which learners are asked to explain how erosion has taken place in each picture.

- Problem-solving group

Learners who share a common interest are presented with meaningful problems to solve. To do so they should share their ideas in order to find solutions (Kempa & Ayob 1991:341-354). For example, learners could discuss and investigate possible strategies to prevent the spreading of AIDS in South Africa.

- Learning together in a group

Learners could work together in small groups when completing a worksheet (Harper 1997:61 and Malan 1997:4). Learners in the group learn to work together by deciding which answers should be filled in on the worksheet.

- Group investigation

Learners in small groups take substantial responsibility for deciding what they will learn; how they will learn; how they will organise themselves to learn, and how they will communicate what they have learned to the rest of their classmates (Lord 1994:281).

To motivate learners to be actively involved in small-group work, learners need to develop specific skills that will enable them to do so.

(a) Skills required for successful small-group work

According to Harper (1997:5); Slavin (1987:53-56) and Watson (1991:141), learners need the following skills to work together in small groups. They should ...

- be able to listen to each other;
- trust each other and value all contributions;
- be prepared to compromise in order to find better ideas or solutions;
- be willing to contribute their ideas to the rest of the group;
- be able to share with the group and
- follow the agreed rules.

To ensure that learners develop these skills while participating in small groups, each learner should be allocated a certain role.

(b) The learner's role in the small group

To ensure that all learners participate actively, each member of the group should receive a role. These roles could include those of leader; timekeeper; fetcher; reader; writer; talker/presenter or leader (Johnson & Johnson 1990:103-107).

Table 5.1 Examples of learners' roles when working in small groups

ROLES	WHAT THEY DO	WHAT THEY SAY
LEADER	Get the process started; motivate the group to complete the task; ensure that everyone has a turn; get them to focus on the task and encourage a specific person to contribute.	Let us begin… Keep going until we have completed…. Each one should have a turn. We are not talking about the task. Let Thandi have a turn.
TIME KEEPER	Checks that the time allocated, is used effectively. Reminds them that time is running out.	We have…minutes left. I think we must move on.
FETCHER	Makes sure that they have the necessary equipment for the task. Ensures that each member of his group obtains what he needs. Responsible for the returning of equipment.	What must I collect? Does everyone have a pencil and a piece of paper? Have you finished; can I return?
WRITER	Captures the meaning of what members of the group have said. Summarises. Helps the group to agree.	Have I written down what you have said correctly? Can we put your idea(s) into fewer words? Do you all agree that I should write….
READER	The reader reads. Directs attention to the text.	Let us see what the books say. Let me read you this paragraph.
TALKER/ PRESENTER	Establishes the manner of presentation.	How should I start? What should I say first? How should I end; or what should I say last?

(Johson & Johnson 1990:103-107 and Malan 1997:5).

Each member of the group should then practice the role appointed to him/her. While learners are working on these co-operative tasks it is the role of the biology teacher to circulate amongst the groups to assist them with suggestions as to how to go about solving problems and at the same time, maintain discipline in the biology classroom. By using the small-group method, learners develop certain skills, which they need to fulfil their role in the group.

(c) Advantages and limitations of the small group method

From the preceding discussion of the small group method it becomes obvious how this method could contribute to the development of process skills. Davidson and O'Leary (1990:30-33); Druger and Vaidya (1996:233) and Shevin (1990:21-29) stress the importance of the small group method further, by supplying the following additional advantages:

- Learners develop communication skills as they have the opportunity to exchange ideas, ask questions freely, explain to one another, and clarify ideas and concepts.
- Certain types of process outcomes can be addressed which are normally overlooked when a strictly lecture mode of instruction is used.
- Learners learn from one another by explaining difficult concepts to each other, which in turn improves the quality of learning.
- Groups learn to handle challenging situations that are well-beyond the capabilities of individuals at a particular developmental stage.

Each small-group activity should be designed to develop certain process skills. Notwithstanding the advantages of the small-group method, there are several limitations that the biology teacher should consider when designing small-group methods when teaching.

When using the small-group method, biology teachers may find the following:

- Learners who lack experience in small-group work may not know what is expected from them.
- While learners talk to each other and do experiments, the biology teacher may lose some control over learners.
- Learners may choose the wrong answers or solutions, if their work is not controlled regularly by the teacher.
- Learners may develop the process skills poorly, without the teacher realising it (Druger & Vaidya 1996:281-289 and Watson & Marshall 1995:291-299).

The success of small-group activities depends on careful planning and a clear understanding of the outcomes as well as the development of process skills by both the biology teacher and the learners.

5.4.2.4 The project method

Miller and Blaydes (1962:4) describe a project as an extended problem or series of related problems that are outgrowths of learners' own interest and endeavours. Van Aswegen *et al.* (1993:80) proposed the following definition of the term *project*: '...a project is a problematic act carried to completion in its natural setting....' A project may be described as a method of spontaneous and incidental teaching, since life is full of projects and individuals may carry out these projects on a regular basis in daily life.

The project method, used as an instructional method, is based on self-activity where learners are actively involved as individuals or in a group, in the solving of a problem from everyday life (Yadav 1992:71). The project method should rise out of a need felt by learners and should never be forced on them. It should be purposeful, significant and interesting. An interesting topic could be suggested by learners and by using process skills such as observations, predictions, inferences and experimenting they could discover as much as possible about this topic. Usually, the project consists of a written piece of work but may involve the collection and preparation of biological material (for example a collection of various shapes of leaves); displays of collected material; constructing and maintaining a living environment (for example, establishing and maintaining a vivarium; terrarium or aquarium) or a comparative study involving plants or animals (Van Aswegen *et al.* 1993:80). The project method should be used as a meaningful, important and useful activity, where learners are encouraged to use resources such as the library and reference books. Learners use the resources to acquire facts which they analyse, evaluate and then learn to integrate as a meaningful whole.

(a) The importance of library integration in project work

Learners should be encouraged to take every opportunity of using the library for research purposes, since the library creates opportunities where learners can develop the skills they need to acquire the variety of available information in encyclopaedias, periodicals, biology textbooks and many other sources. From the sources learners learn to select, interpret and synthesise information which they have acquired from the library. This gathering of new information is intellectually stimulating and enables learners to become familiar with terminology and subject language in general. Project work in the library is also essential for the professional growth of biology teachers, since it refreshes and updates their knowledge. Furthermore, it is also necessary for learners because they acquire information and an understanding, which is not always covered in the biology classroom. In fact, it is not possible for a biology teacher to cover everything in-depth, in the classroom. Most biology teachers, thus far, have not made an effort to make the best use even of the limited resources at their disposal (Druger & Vaidya 1996:220). The biology teacher has an important role to play to enable learners to be successful in their project work.

(b) The role of the biology teacher

At most, a biology teacher should suggest the projects that should be done, but should not indicate *who* or *how* learners should do it. The biology teacher assists learners to solve problems; encourages them to work collectively; aids learners to avoid mistakes and ensures that each learner contributes something in order to complete the project (Yadav 1992:70-72 and Druger & Vaidya 1996:223). Once the project is completed, the teacher needs to assess learners' efforts and give feedback in the form of written or oral comments. To be able to do this, it is essential that the biology teacher is well-read and well-informed, so that he/she can help learners to be successful in the completion of the project.

(c) Advantages of the project method

There are many concrete and indirect advantages to the project method. The project method can...

- encourage learners to select their own problem to study and thus stimulate interest and encourage a sense of commitment and personal responsibility for the task, rather than choosing a task where only the teacher's requirements are met;

- enable learners to construct knowledge by active involvement, rather than by mere transfer of information;

- enable learners to practice and develop process skills and develop positive attitudes and values towards biology rather than only the acquisition of irrelevant biology information;

- satisfy and promote curiosity and ingenuity in problem-solving;

- provide sufficient opportunities for developing personality traits, like persistence, self-confidence, co-operation, leadership and emotional stability;

- develop problem-solving techniques and
- encourage independent and critical thinking (Bliss 1990:391-392; Hussain 1989:144; Powell 1987:218 and Van Aswegen *et al.* 1993:82).

(d) Shortcomings of the project method

As with all the methods mentioned previously, the project method also has numerous limitations that prevent some biology teachers from using it. The following reasons have been encountered:

- The method is too time consuming for both learners and teachers.
- There may not be enough material, apparatus, or books for all the learners in the classroom.
- It is an expensive method because it involves tours, excursions, purchase of apparatus and equipment and other resources.
- The method of organising instruction is unsystematised and may thus upset the regular flow of the timetable (Druger & Vaidya 1996:222-224; Williams 1984:2 and Yadav 1992:75).

Despite the difficulties associated with project work, this method should occupy a definite place in developing process skills and ought not be regarded as an inefficient use of either teachers' or learners' time, and should supplement existing strategies. Project work can contribute to the development of process skills which learners need for life-long learning. According to Bliss (1990:393), the intensity of satisfaction a learner may get out of a project is a facet that no other teaching method achieves.

5.5 SUMMARY

A few instructional methods that might contribute to the successful development of process skills were discussed. This, however, does not exhaust the methods available to the biology teacher to develop learner's process skills.

The best way to develop process skills are to use a particular strategy which involves learners actively engaging in problem - solving activities. The problem - solving strategy enables learners to use and apply content and to discover for themselves. It is important that the biology teacher selects instructional methods that will best develop problem - solving skills.

As no particular method can considered adequate when used on its own, it is important that biology teachers should select a possible combination of methods which might best contribute to the development of process skills. According to Mossom (1989); Harper (1997) and Mhlongo (1997) the best way to develop process skills is through inquiry methods. Inquiry methods offer learners the opportunity to read, study, analyse and synthesise information from a variety of sources from which they have to recall appropriate facts, concepts and solutions when drawing conclusions.

Inquiry methods that have been selected to develop process skills are the questioning method, practical work (which includes laboratory and field work), the project method and the small group method (co-operative learning method). These methods were discussed, as well as some of their advantages and limitations.

Notwithstanding, the similarities between *Curriculum 2005* or *21* and a process approach and the advantages of a process approach to enhance life-long learning, there is a virtual absence of implementing a process approach in the biology classroom. Therefore, it is important to determine why a process approach is not successfully implemented in biology education.

In the next chapter the research design that was used to determine the possible problems that might hamper the implementation of a process approach in secondary school biology classes, will be described.

CHAPTER SIX

DESIGN OF EMPIRICAL INVESTIGATIONS

6.1 INTRODUCTION

In this chapter the design of the research that was used to investigate the extent to which a process approach is not successfully implemented in secondary biology education (vide 2.2) is described. Data was obtained by means of questionnaires (vide Appendix A2) and interviews (vide Appendix A3). The construction, piloting and administering of questionnaires and the interview schedule will also be discussed in this chapter.

A qualitative research was undertaken. The empirical research was conducted in the Gauteng Province, in both historically disadvantaged (HD) and historically advantaged (HA) secondary schools. As the Gauteng Province consists of 655 secondary schools random sampling was used to choose a 15 percent sample. The sampling method will be described in the last part of the chapter and the actual sample will be illustrated in Table 6.8. Interviews were held with subject- and education specialists. Table 6.1 contains details of these interviews.

6.2 REVIEW OF THE PROBLEM

The problem that triggered this study is the apparent lack of implementation of basic- and integrated process skills in the teaching and learning of biology. The following questions have been raised in section 1.2 that elucidate the problem further:

- How can the factors that may hamper the development of learners' process skills be addressed?

- How can pre- and in-service training contribute to the successful implementation of a process approach?

- How can a variety of teaching and learning methods be used to facilitate the development of learners' skills?

- How can the principal, biology teachers and parents' participation in the implementation of a process approach be enhanced?

- How can the development of learners' process skills be assessed?

Throughout the literature study, it was argued that the development of process skills is necessary to ensure that learners will acquire and apply information in everyday situations.

6.3 RESEARCH DESIGN

Biology teachers of HD and HA schools and subject- and education specialists' responses on the possible reasons why a process approach is not implemented successfully, were obtained through questionnaires and interviews. The researcher chose these methods in the research in an attempt to uncover the hidden perspectives held by biology teachers, subject- and education specialists. Teachers were to take an active role in the research by suggesting teaching strategies and possible factors that might hamper the implementation of a process approach. It is important to note that the methods followed in this study exhibits characteristics typical of the qualitative research methodology. The purpose of this type of research is not generalisation as such, but a better understanding of a situation from the participants' points of view. Therefore, qualitative information is not dependant on large numbers of respondents. The ideal is to proceed with interviews and analyses of questionnaires until a point of theoretical saturation is reached.

6.3.1 Questionnaires

Questionnaires can be used by researchers to directly analyse information. Hopkins (1985:41) states that questionnaires which ask specific questions about aspects of the classroom, curriculum or teaching methods, are a quick and simple way of obtaining information from teachers. Questionnaires enable the researcher to measure what a teacher knows (information), what a teacher thinks (attitude and beliefs) and what a teacher dislikes (values and preferences).

Hopkins (1985:42) clearly indicates the criteria that the researcher must constantly apply in preparing questionnaires and interviews as follows:

- To what extent might a question influence respondents to be unduly helpful by attempting to anticipate what researchers want to hear or find out?

- To what extent might a question influence respondents to show themselves in a good light?

- To what extent might a question be asking for information about respondents that they are not certain, and perhaps not likely, to know about themselves?

The validity of questionnaire items will be limited by all three considerations. Thus, the advantages and disadvantages of the questionnaire or as a source of data must be considered in each specific case before a decision can be made.

Hopkins (1985:34) maintains that questionnaires like interviews, are a way of getting data about people by asking them rather than watching their behaviour. The self-report approach incorporated in questionnaires, presents certain limitations. Sometimes these techniques measure not what people believe; not what they like but what they say they like.

The reasons for choosing questionnaires for this study are as follows:

- Questionnaires, if well designed, are easy to administer, follow up and their data can be quantified if necessary.

- Questionnaires can be an appropriate tool for collecting information from samples spread over a certain geographical area.

- The questionnaires provide anonymity to the respondents. As a result respondents are expected to respond more willingly, openly and honestly to the questions.

- Questionnaires facilitate the obtaining of facts and opinions about current conditions in schools and practices.

- Questionnaires are extremely effective for gathering information from a number of teachers (Hopkins 1985:34).

Extensive preparation of the questionnaire is necessary to get clear, unambiguous and relevant questions. It was decided to undertake an empirical investigation by means of questionnaires. A draft questionnaire was developed which incorporated various aspects of teaching a process approach and factors that might hamper the successful implementation of a process approach gleaned from the literature, as well as from the researcher's personal experience as a secondary school teacher.

In the development of the questionnaire, the researcher was aware that the improvement of academic and professional qualifications constitutes only a small part of the implementation of a process approach scenario. Teachers need to grasp the opportunity to renew and extend their professional and facilitation expertise as continuous changes are taking place in education.

6.3.1.1 Aspects to consider when compiling a questionnaire

The following aspects have to be taken into consideration when compiling a questionnaire (Hopkins 1985:34-36):

- *The purpose of the questionnaire:* Will depend on the aim of the research as well as the method of its application.

- *The experiential world of the respondent*: Respondents must be familiar with the questions asked.

- *The means of data collecting:* The construction of a questionnaire should be easy to complete in a limited time.

A questionnaire is designed in such a way that it answers specific research goals. Each question should therefore be carefully formulated. A questionnaire should not be evaluated globally, but each question must be carefully weighed to determine whether the response will help to provide the best answer to the research problem (Grossman 1994:65).

According to Hopkins (1985:35), a question in the questionnaire should meet the following requirements:

- It requires extensive preparation.

- It should be related to the research problem and the research objectives.

- It should be unambiguous.

- It should be relevant.

- It should not be biased.

Hopkins (1985:38) also mentions the following properties of a questionnaire that need to be considered:

- The topic or theme must be such that the respondent sees it as important so that he/she will be prepared to co-operate in completing the questionnaire.
- The questionnaire must be attractive, brief and as easy as possible to complete.
- Instructions should be clear and be given at the beginning of the questionnaire.
- Items should not ask for a moral, ethical standpoint.

6.3.1.2 Question format

Two basic formats were used in the development of questionnaires, namely, open questions (also called unstructured questions) and closed questions (also called structured questions). Various combinations of these two formats may be used.

- **Unstructured questions (open questions)**

Grossman's (1994:2) analyses and summary of an open question can be defined as one that supplies a frame of reference for a respondent's answers, but puts a minimum restraint on the answers and their expressions. Although the content of the respondent's answer is dictated by the research problem or question, there Is no other restriction on the content and manner of the respondent's answers. The advantage of open questions can be that they enable the researcher to make better estimates of respondents' intentions, beliefs and attitudes.

- **Structured questions (closed questions)**

Structured questions, also called closed or fixed-alternative items, offer the respondent a choice among two or more alternatives. The main advantages of structured questions are that uniformity can be achieved, they are more economical and less time-consuming to administer than is the case with open questions (Grossman 1994:2).

The major disadvantage of structured questions is the loss of report between the person administering the questionnaire and the respondent. The respondent may also experience that the given responses do not always make adequate provision for the expression of his/her personal opinion or feelings. Worse, responses can be forced as a respondent may choose an alternative to conceal his/her ignorance or have no other option to choose from. Structured questions are also less subtle than open questions.

For the purpose of this study, both structured and unstructured questions were used. The structured questions are used for sections A and B while the unstructured questions are used for section C. Section C enables respondents to make comments based on their expertise and experience, to express their opinions and to make recommendations.

6.3.1.3 Structure of the questionnaire

The questionnaire was structured for biology teachers of HD and HA schools. The structure of the questionnaire needs to be logical and clear to the respondents. In accordance with the aims of the questionnaire, the researcher decided to divide the questionnaire into three sections. The sections are as follows:

Section A: Deals with general information.

Section B: Deals with a process approach.

Question 1: Do teachers know what a process approach is?

Question 2: Do they know what basic- and integrated skills are?

Question 3 deals with the characteristics associated with a process approach.

Question 4 deals with the frequency inquiry activities are used by the biology teacher.

Question 5 deals with possible factors that might influence the implementation of a process approach.

Question 6: Teachers had to indicate for whom the development of process skills were the most valuable.

Section C: Deals with additional comments of biology teachers.

The layout or design of the questionnaire was done according to a standard format used at the University of South Africa's Research Department to suit SPSS computer analysis. The questionnaire focused on the responses and comments of biology teachers from HD and HA schools on...

- some of the characteristics associated with a process approach;

- factors that might hamper the successful implementation of a process approach;

- the frequency of using inquiry activities in HD and HA schools respectively and

- the value of the development of process skills for learners.

The questionnaire proved to be a method for obtaining data about the possible reasons why a process approach is not implemented successfully. In addition, it afforded respondents the opportunity of expressing, without inhibitions, their feelings and their experiences. This was reinforced by complete anonymity.

6.3.1.4 Length of the questionnaire

The length of the final questionnaire needs due consideration when compiling it. Hopkins (1985:34) claims that the final length of the questionnaire can determine the reliability and validity of a research. In conclusion the questionnaire should not be to short or to lengthy to ensure that it is reliable and valid. The researcher avoided long questions or items since these could lead to respondent fatigue and misinterpretation.

6.3.1.5 Questionnaires sent to sampled biology teachers

(a) Pilot survey of the questionnaire

After compiling the items, it is important to evaluate and reconsider their inclusion in the questionnaire. Before the questionnaire was finalised and used to gather the biology teachers' data from HD and HA schools, a pilot study was carried out in the North Gauteng Province to test questions for *inter alia*, vagueness and ambiguity and to ascertain whether items were correctly structured or not.

Ten school teachers of Grades 8-12 from seven HD (4) and HA (3) schools in the North Gauteng Province, were involved in the pilot study. The schools were randomly selected and grouped as follows:

- Four HD schools in Mamelodi (2) and Atteridgeville (2),
- Three HA schools in Pretoria East (2) and Pretoria North (1).

Teachers' responses and comments were noted during the pilot survey and several items were modified. The questionnaire was also given to lecturers at the Teacher Training institution in Soshanguve (vice-principal and Head of Department of biology[HOD]) for comments and improvements. From this a final draft of the questionnaire (see Appendix A2) was prepared. The questionnaire was then finalised and approved by Unisa's Institute of Educational Research.

(b) Administering the questionnaire

The purpose of administering the questionnaire to a representative sample is to obtain statistical data about each item listed. The respondents were secondary biology school teachers, HODs and vice-principles residing in HD and HA schools.

The questionnaire was harnessed to gather information about possible teaching methods teachers use and possible factors that might influence the implementation of a process approach.

Some questionnaires were personally taken to biology teachers and others posted to the selected schools. This was done by the researcher and subject facilitators in April 2000. Each questionnaire was accompanied by two letters. The letter from the Gauteng Department of Education indicating permission to undertake the research study (see Appendix B) was included with the questionnaire. The second letter addressed to biology teachers (see Appendix A1) indicated the purpose of the questionnaire and gave an assurance that neither individual teachers nor schools will be identified in the study.

From the data collected through regional random sampling, it is possible to make reliable inferences about the population from which the sample was drawn. One cannot deny the fact that even if the sample is drawn randomly, it is never a completely accurate reflection of the population. The researcher worked within this limitation. Further factors such as teachers' willingness to complete the questionnaire affected this study to a great extent. Teachers who did not return their questionnaires were telephonically requested to do so. Many sampled teachers asked for another questionnaire as they had 'misplaced' the previous one.

6.3.2 Interviews

6.3.2.1 The interview schedule

Mhlongo (1997:28) defines an interview as: 'A direct method of obtaining information in a face-to-face situation'. The interviewee gives the needed information verbally in a face-to-face relationship rather than writing the response. The interview method of collecting data is flexible and can be easily adapted to a variety of situations. Through the interview technique, the researcher may stimulate the respondent to greater insight into his or her own experiences and thereby explore important areas not anticipated originally by the interviewer (Mhlongo 1997:87).

The main reason for the flexibility of this method is the presence of the interviewer who can explore responses with the interviewee, ask further questions for the clarification of certain points and control the interview to elicit responses. Interviews were conducted, as they can be valuable data gathering tools for gathering information in areas where a deep understanding is needed and where probing might be required.

6.3.2.2 Construction of the interview schedule

A structured but open interview schedule was required so as not to place too much restriction on the responses given. The flexible approach permitted the interviewer to pursue certain responses as far as was necessary, to follow important clues or to obtain additional information. The researcher constructed an interview schedule which consisted of a set of questions that the interviewer asked each respondent (see Appendix A3). In this study, the interview schedule was intended for the senior educationists and subject specialists. The interview schedule comprised of six open-structured questions for the second group of the respondents in this study (vide Table 6.1). The respondents were interviewed in their offices. Interviews lasted for at least 30 minutes per interviewee. As some of the interviewees requested that some of their comments be dealt with anonymously, names were not included in the analysis of the interviews but were used where applicable for recommendations and the literature study in this research.

6.3.2.3 Piloting and administering the interview schedule

(a) Pilot survey of the interview schedule

A pilot survey of the interview schedule was undertaken with a group of persons similar to the respondents used in the actual investigation. In this case one respondent from each post category was interviewed. The main reasons for piloting the interview schedule were to...

- correctly identify the errors and weaknesses in the interview schedule;
- provide vital training for the researcher as an interviewer and
- improve the questions' potential for eliciting relevant information by taking heed of constructive comments of colleagues in the field.

Factors such as race, age, religion, vocabulary, accent, ethnic background and social class of the interviewer which can influence the reliability and validity of the responses because the interviewer and some of the interviewees were not of similar background.

(b) Administering the interview schedule

Interviews demand a lot of time, so only one vice-rector, one associate professor, four biology lecturers, two didactic lecturers, three heads of department Didactics (HODs), one emeritus professor in Didactics, three education policy developers, one Examination and Certification officer, one head director of Policy Development, one deputy-director of Curriculum Development and one director of OBE Program were interviewed. These interviews were used to collect data, which was in turn used in a qualitative manner to yield findings reported later in this study. As mentioned earlier, qualitative information is not dependant on large numbers of interviewees.

The following table shows the population involved in the interviews. Interviews were conducted in 1996 and again in 2000. The reason for the follow-up interviews was initiated by changes that took place in education in general. District Officials were also included in this study as their hierarchical positions may influence the outcome of the research.

Table 6.1 Details regarding interviewees

INSTITUTIONS	INTERVIEWEES	POST HELD
1 Colleges	1	Vice-Rector
	1	Associate Professor
	1	Biology Lecturer
2 Universities	3	Biology Lecturers
	2	Didactic Lecturers
	3	Heads of Department (Didactics)
	1	Emeritus Professor in Didactics
3 District Office	3	Education Policy Developers
	1	Examination and Certification
	1	Head Director of Policy Development
	1	Deputy-Director of Curriculum Development
4 OBE-expert	1	Director of OBE Program

(c) Interviewing

Each interview commenced with an introduction and an explanation of the purposes of the investigation. For some interviews, permission for the use of a tape recording was requested. Interviewees were invited to openly discuss their experiences and possible problems encountered in the South African education system or biology education as such.

Although they were assured of the anonymity of their responses, the researcher specifically asked if certain comments could be used as possible recommendations in this research, which were agreed upon.

They were also requested to make, wherever possible, suggestions for solutions to problems. These problems, largely indicated spontaneously, constituted the core of possible factors that might prevent the implementation of a process approach. The 19 interviews conducted are considered as sufficient for the purpose of the study; in the last few interviews there were indications that the so-called theoretical point of saturation was being reached, as many of the information was repeated by different interviewees.

6.3.3 Validity and reliability of interviews and questionnaires

Validity in qualitative investigations is not as much dependent on the number of respondents as on the extent to which a respondent reflects a true picture of a specific cultural experience - and reflected as such by the researcher (Lemmer 1992:292). The researcher believes that her experience as biology teacher and researcher in HA and HD schools places her in an excellent position to form opinions on the possible factors that might hamper the implementation of a process approach in biology education in different communities as well as to identify possible inequalities and disparities in this regard.

The views of biology teachers of HD and HA secondary schools and lecturers, officials and researchers attached to different institutions and departments reflect in an unambiguous way the factors that can possibly hamper the implementation of a process approach. Of the respondents who had to complete the questionnaires, only 19,40 percent of HD schools' teachers did not return their questionnaires. The 80,6 percent who responded enabled the researcher to conduct valid research along with the interviews held with subject- and education specialists. Data is consequently considered as reliable.

6.4 DELIMITATION OF THE STUDY AREA

South Africa consists of nine provinces. Although all nine provinces can deliver valuable information on why a process approach is not successfully implemented in secondary schools, this research study is limited geographically to Gauteng Province. The Gauteng Province represents both HD and HA secondary schools and can be considered as a focus area that will deliver valuable inputs.

To facilitate planning, control and administration of all schools, the Province is divided in three regions, namely, Central Gauteng, North Gauteng and South Gauteng. These regions can be divided into several districts as indicated in Table 6.2 below.

Table 6.2 Regions and districts in Gauteng (Gauteng Education Department [2000a]).

REGIONS	NO OF DISTRICTS
North Gauteng	7
South Gauteng	5
Central Gauteng	6
Total	18

6.4.1 Number of secondary schools in Gauteng Province (historically disadvantaged [HD] and advantaged [HA] schools)

The number of secondary schools in the Gauteng Province was obtained from the Data Basis Education Management Information Systems on 16 March 2000.

Table 6.3 Number of secondary schools in Gauteng Province

REGION	DISTRICT	NO. OF DISADVANTAGED SCHOOLS	NO. OF ADVANTAGED SCHOOLS	TOTAL
Gauteng Central	C1	33	2	35
	C2	22	5	27
	C3	36	51	87
	C4	23	2	25
	C5	25	21	46
	C6	28	16	44
Total	6	167	97	264
Gauteng North	N1	23	8	31
	N2	21	6	27
	N3	24	20	44
	N4	21	2	23
	N5	29	12	41
	N6	19	5	24
	N7	12	0	12
Total	7	149	53	202
Gauteng South	S1	34	9	43
	S2	41	3	44
	S3	30	15	45
	S4	30	1	31
	S5	22	4	26
Total	5	157	32	189
	18	**473**	**182**	**655**

A total number of 655 secondary schools exist in Gauteng Province. The precise number of secondary schools offering the subject biology is, however, not known.

To make the sample as representative as possible 49 of HD and 49 of HA secondary schools were selected from the three regions of Gauteng Province. As there might be more than one teacher involved in biology teaching the researcher requested each school telephonically that all the biology teachers of that school should come together and complete the questionnaire. This was done, as factors which may hamper the implementation of a process approach might be the same for a specific school.

HA schools were included in the sample as these are institutions where some biology teachers might teach smaller classes, and have more teaching equipment available in contrast to some HD schools (which also include farm schools), which might have large classes, underqualified teachers and minimum infrastructure. It is therefore assumed that HA schools may present a different view concerning the successful implementation of a process approach in biology education. This assumption, however does not imply that HA schools are free from educational constraints.

6.4.2 Sampling of secondary schools

6.4.2.1 HD and HA schools

Random sampling was used to choose a 15 percent sample. The Gauteng Education Department (2000a:1-8) indicates that there are 655 secondary schools in Gauteng Province (see Table 6.3). The 15 percent sample, i.e. 98 schools, was selected in the following way:

(a) Pieces of paper were numbered 1-655 as indicated below:

Numbers	*Regions*
1 - 264	Central Gauteng
265 - 466	North Gauteng
467 - 655	South Gauteng

(b) The pieces of paper were folded and placed in three holders which represent the three different Provinces of Gauteng.

(c) An independent person drew a total of 98 pieces of paper from the three holders as illustrated in Table 6.4.

The above method yielded the following sample with respect to the number of schools to be selected in the three regions of Gauteng.

Table 6.4 The sampled schools selected in the regions of Gauteng Province for the study

REGION	NO. OF SECONDARY SCHOOLS
Central Gauteng	40
North Gauteng	30
South Gauteng	28
Total	98

To ascertain the number and the names of these secondary schools in Gauteng Province a second method, described below, was used. Central Gauteng is used as an example.

(a) The number of secondary schools in Central Gauteng was ascertained from Table 6.3 i.e. C1 = 35; C2 = 27; C3 = 87; C4 = 25; C5 = 46; C6 = 44.

(b) The total number of these schools in the Central region was obtained from Table 6.3 i.e. 264 schools.

(c) 264 pieces of paper were numbered 1-264.

(d) From lists of schools obtained from the Gauteng Education Department (2000a:1-8) the names of the 264 schools were written on pieces of paper C1: 1-35; C2: 36-62; C3: 63-149; C4: 150-174; C5: 175-220; C6: 221-264.

(e) These numbers were placed in six different holders representing the six districts in Central Gauteng.

(f) From the numbers 1-35, 6 were drawn; from 36-62, 4 were drawn; from 63-149, 11 were drawn; from 150-174, 3 were drawn; from 175-220, 8 were drawn; from 221-264, 8 were drawn; totalling 40 pieces of paper.

These 40 pieces of paper indicated the names of the secondary schools to which questionnaires had to be sent in Central Gauteng.

The above method was also used to determine the sample in the other two regions of Gauteng Province. Table 6.5 illustrates a summary of the distribution and it also denotes the number and percentage of secondary schools that were selected from Gauteng.

Table 6.5 Summary of sampling method in the three regions of Gauteng Province indicating the number and percentage of secondary schools.

REGION 1: CENTRAL GAUTENG							
Districts	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**Total**
No. in region	35	27	87	25	46	44	264
%	13,26	10,23	32,96	9,46	17,42	16,67	100
School numbers	1-35	36-62	63-149	150-174	175-220	221-264	264
No selected	6	4	11	3	8	8	40
%	2,27	1,51	4,16	1,13	3,03	3,03	15,13

REGION 2: NORTH GAUTENG								
Districts	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**Total**
No. in region	31	27	44	23	41	24	12	202
%	15,34	13,37	21,80	11,39	20,30	11,90	5,94	100
School numbers	1-31	32-58	59-102	103-125	126-166	167-190	191-202	202
No selected	4	4	7	3	7	3	2	30
%	1,98	1,98	3,47	1,49	3,47	1,49	0,99	14,87

REGION 3: SOUTH GAUTENG						
Districts	**S1**	**S2**	**S3**	**S4**	**S5**	**Total**
No. in region	43	44	45	31	26	189
%	22,75	32,28	23,80	16,40	13,77	100
School numbers	1-43	44-87	88-132	133-163	164-189	189
No selected	7	7	7	4	3	28
%	3,70	3,70	3,70	2,11	1,59	1,48

A summary of the secondary schools in the entire Gauteng Province to which questionnaires for biology teachers had to be sent is reflected in Table 6.6.

Table 6.6 Summary of secondary schools in the Gauteng Province to which teacher questionnaires had to be sent

DISTRICT	1	2	3	4	5	6	7	Total
Central	6	4	11	3	8	8		40
North	4	4	7	3	7	3	2	30
South	7	7	7	4	3			28
Total	17	15	25	10	18	11	2	98
%	17,35	15,3	25,5	10,20	18,37	11,23	2,05	100

6.4.3 Sampling for interviews

A mixture of qualitative sampling techniques were employed in the study, namely:

- Purposeful sampling (i.e. careful selection of information - rich key informants at universities, college and technikon).
- Network ("snowball") sampling (i.e. personal references by interviewees.
- Some random sampling (i.e. interviewees from HD and HA institutions).

Using the above techniques a list was compiled of some education- and subject specialists that can possibly contribute to this research. Interviewees were telephonically contacted and an appointment made for a interview. As not all purposeful and randomly sampled interviewees were available, the researcher made use of network sampling where interviewed specialists referred other specialists that could possibly assist with the research.

6.4.4 Permission to conduct research study

Permission to undertake the research study in secondary schools of Gauteng Province was requested from the Gauteng Department of Education. This permission was granted in March 2000. The reply granting permission for the use of primary schools for this research was received in the letter dated 28 March 2000 (see Appendix B).

6.4.5 Problems encountered

Receiving the questionnaire from some of the schools that were selected by random sampling technique was sometimes difficult to execute. The reasons for this were:

- Many teachers did not complete the questionnaire and had to be reminded again to send it back. This was done by telephoning every school which did not respond. The concept 'process approach' was also explained to those who did not know what it meant.

- Some teachers misplaced the questionnaires.

- Duplicates of questionnaires had to be posted to several schools.

- A few teachers responded by indicating that they did not have time to complete the questionnaire.

The actual sample to which questionnaires were sent is shown in Table 6.6. Also indicated in the table is the number and percentage (%) of secondary schools, the projected sample and the actual sample of the research study.

Table 6.7 Actual sample in relation to the total number of secondary schools in Gauteng and the projected sample.

SECONDARY SCHOOLS IN GAUTENG			PROJECTED SAMPLE		ACTUAL SAMPLE	
Region	No.	%	No.	%	No.	%
Central	264	40,30	40	15,32	35	13,27
North	202	30,85	30	14,88	24	11,88
South	189	28,85	28	14,80	20	10,85
Total	655	100	98	15	79	12

The actual sample represented 79 and the projected sample 98 of the 655 secondary schools in Gauteng Province. As only 10 HD schools' biology teachers did not participate in the research study the projected (15%) and actual sample (12%) did not differ dramatically from one another to have an affect on the research study.

Table 6.8 illustrates the projected and actual sample of HD and HA schools' teachers.

Table 6.8: Number of questionnaires completed and returned

	NO. DESPATCHED			NO. COMPLETED AND RETURNED			% RETURNED		
	HD	HA	Total	HD	HA	Total	HD	HA	Total
Central	20	20	40	15	20	35	75	100	8,5
North	15	15	30	9	15	24	60	100	82,14
South	14	14	28	6	14	20	64,28	100	73,33
Total	49	49	98	30	49	79	61,42	100	80,60

6.4.6 Return of questionnaires

As can be seen in Table 6.8, 79 of the questionnaires despatched to biology teachers were completed and returned, representing and overall return of 80,60 percent of the respondents. Of HD schools' teachers 30 (61,22%) responded and of the HA schools' teachers 49 (100%).

6.5 SUMMARY

This chapter discussed the methodology used to collect data for this research. Questionnaires and interviews were used for this purpose.

A stratified random sampling frame was selected, because it ensured the widest coverage of the research area.

The development of questionnaires and interview schedules is a difficult and time-consuming task. Although an attempt was made in this chapter to provide guidelines and criteria for the development of these instruments, there are no fixed rules. However, the researcher tried to ensure that the instruments are practical and practicable.

An attempt was made to follow the guidelines and criteria mentioned in this chapter on the implementation of the instruments. Chapter Seven contains an analysis of the responses to the instruments and the interpretation of the results.

CHAPTER SEVEN

FINDINGS OF EMPIRICAL INVESTIGATION

7.1 INTRODUCTION

This chapter is mainly concerned with presentation of findings and analysis of data from the questionnaire. The empirical investigation attempted to determine the possible factors that might influence the implementation of a process approach.

In this chapter the responses of biology teachers to the questionnaire will be analysed.

7.2 FINDINGS OF QUESTIONNAIRE SURVEY

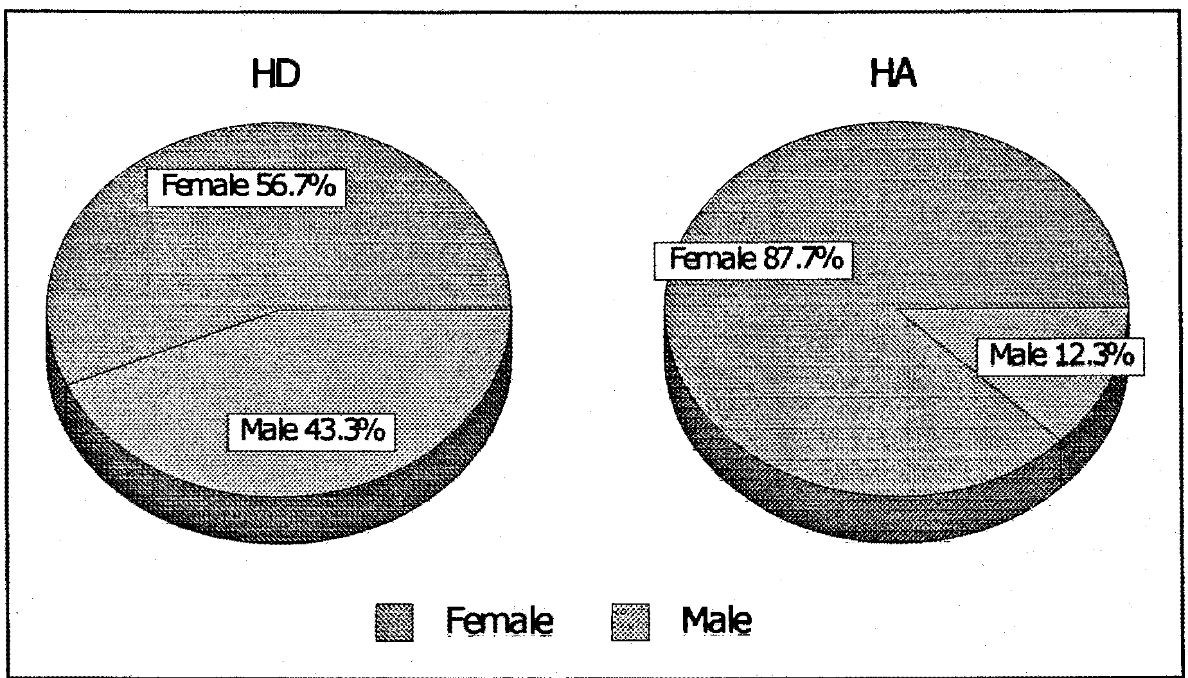
7.2.1 Respondents' characteristics

7.2.1.1 Respondents by gender and school type

For the purpose of this study the gender factor was not regarded as a significant variable. The information gathered from the survey will be used for contextual background.

An interesting finding is of a total of 79 teachers participating in the study, 56,7%(17) of HD schools' teachers were females and 43,3%(13) males, while 12,3%(6) males and 87,75%(43) females of HA schools' teachers responded. As can be seen in Figure 7.1 below the ratio of males:females in this research study for HD schools is nearly 43,57:56,7 while HA schools is 12,3:87,75.

Figure 7.1 Composition of the questionnaire respondents by gender and by school type



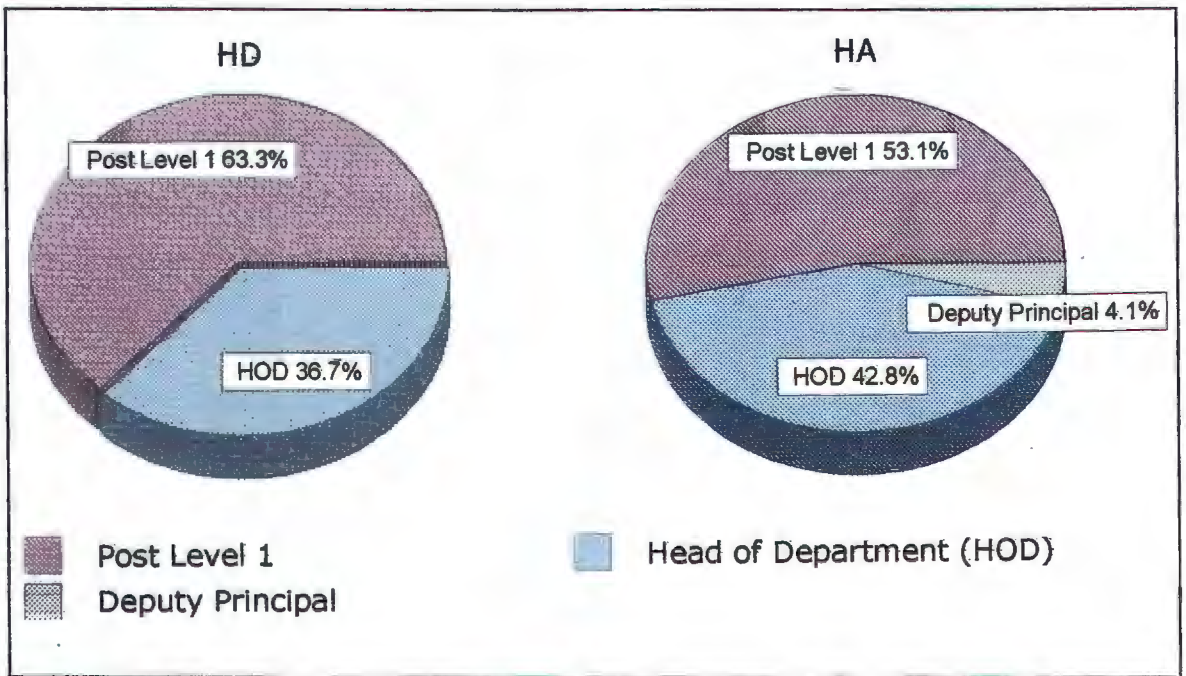
HD	HA
n = 30 Female = 17 Male = 13	n = 49 Female = 43 Male = 6

7.2.1.2 Professional status of teachers

It can clearly be seen from Figure 7.2 that the majority of respondents (HD and HA schools) are post level 1 biology teachers. Post level 1 teachers can either be senior or junior biology teachers of a school who have not applied or been promoted to post level 2, namely HOD. The percentages for post level 1 teachers range from 63,3%(19) for HD to 53,10%(26) for HA schools' teachers. Of HD schools' HODs, 36,7%(11) completed the questionnaire and of HA schools' HODs, 42,8%(21). Two Deputy Principals of HA schools responded.

Determining the professional status of biology teachers who responded, can be considered as an important aspect of this survey. According to research conducted by Isaac (1990:313) most post level 1 biology teachers and HODs regard examination results as very important as their promotion opportunities will be enhanced by good results on the part of the learners. This exam-orientated teaching strategy of biology teachers may affect the successful implementation of a process approach.

Figure 7.2 Respondents' professional status



HD	**HA**
n = 30 Post level 1 = 19 HODs = 11	n = 49 Post level 1 = 26 HODs = 21 Deputy Principal = 2

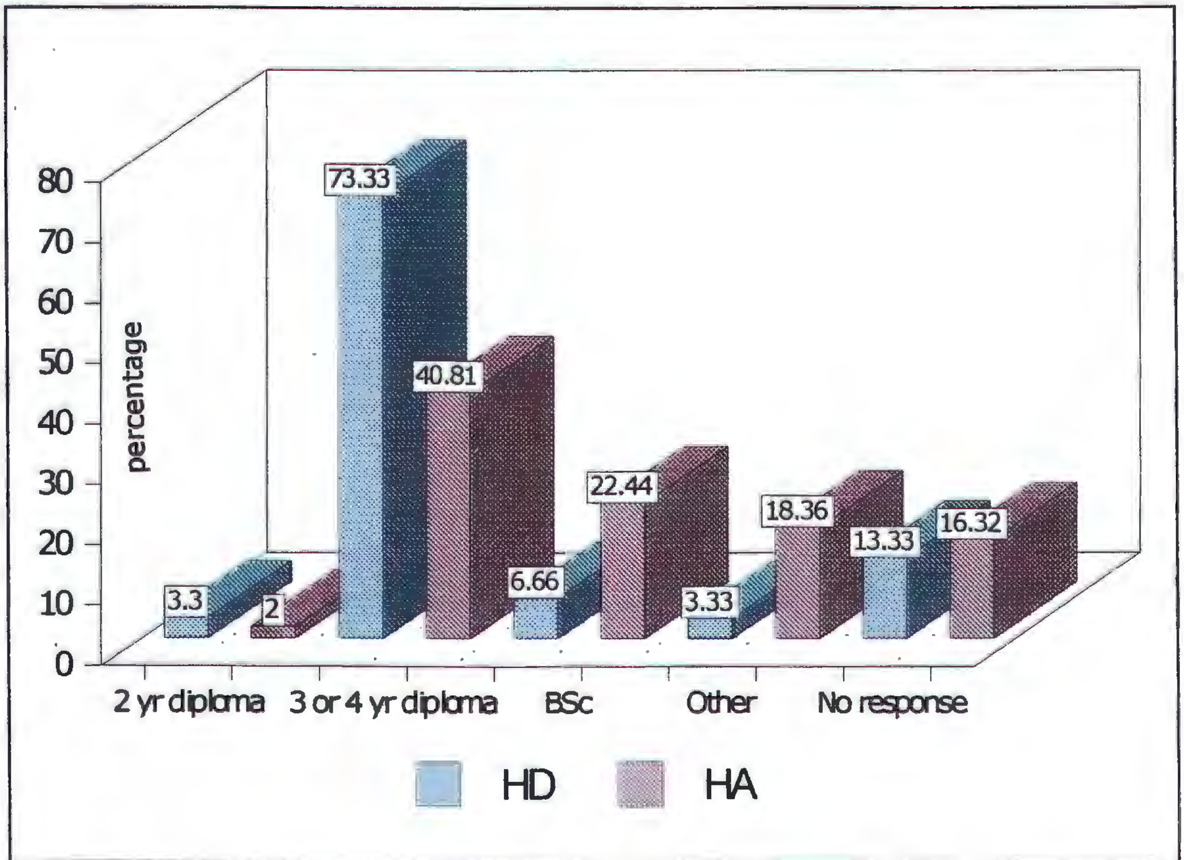
7.2.1.3 Academic qualifications of biology teachers who responded

The responses of teachers concerning their academic and highest qualifications, as well as their experience in teaching biology, might be necessary as qualifications may contribute to the implementation of changes in secondary biology education.

With reference to the academic qualifications of respondents, the data in

Figure 7.3 reveals the following: of the 79 questionnaires only 67 responded to this question; 86,66%(26) of HD schools and 81,63%(40) of HA schools.

Figure 7.3 Academic qualifications of respondents at historically disadvantaged (HD) and historically advantaged (HA) schools

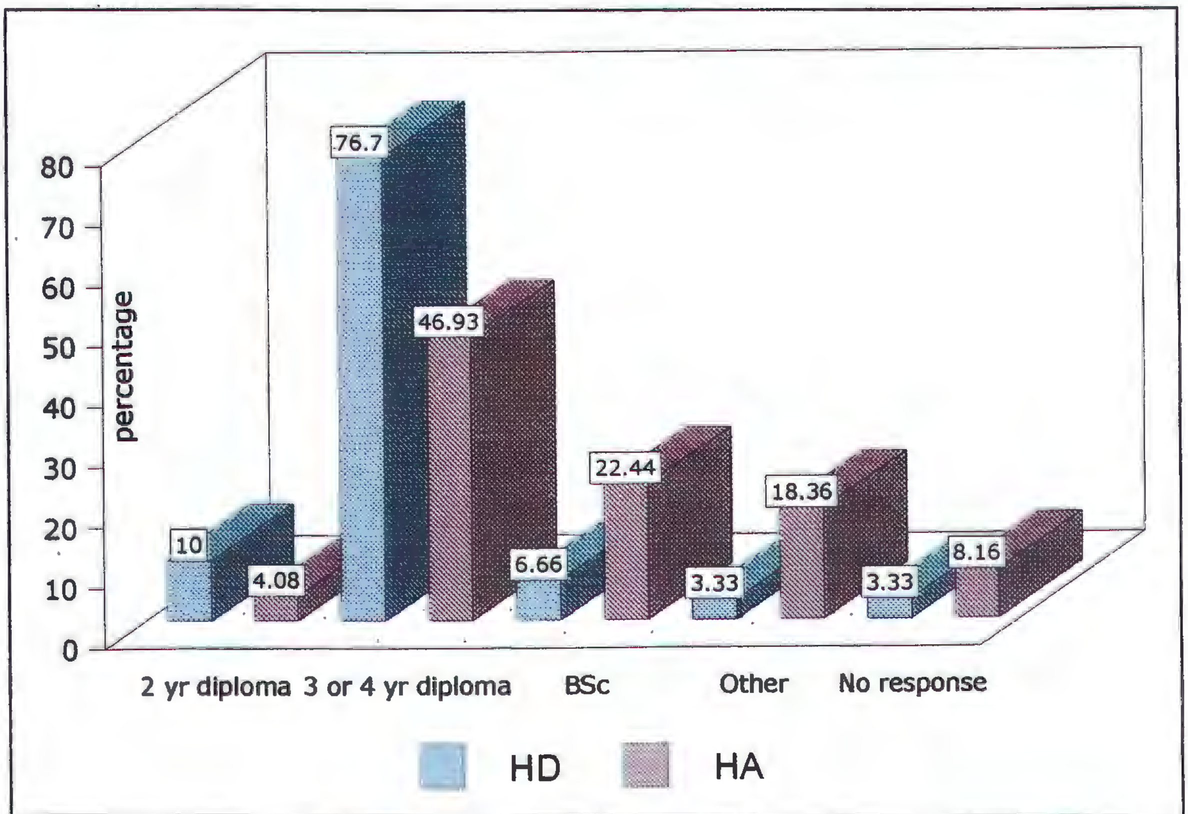


HD	HA
n = 30	n =49
2 year diploma = 1	2 year diploma = 1
3 or 4 year diploma = 22	3 or 4 year diploma = 20
BSc = 2	BSc = 11
Other = 1	Other = 8
No response = 4	No response = 9

7.2.1.4 *Highest qualification of HD and HA schools' teachers to teach biology*

An analysis of the responses from 30 teachers employed at HD and 49 at HA schools concerning their highest qualification to teach biology, appears in Figure 7.4

Figure 7.4 Highest qualification of biology teachers in HD and HA schools



HD	**HA**
n = 30	n = 49
2 year diploma = 3	2 year diploma = 2
3 or 4 year diploma = 23	3 or 4 year diploma = 23
BSc = 2	BSc = 11
Other = 1	Other = 9
No response = 1	No response = 4

(a) The majority of teachers have a 3 or 4 year diploma: 76,7%(23) HD schools' teachers and 46,9%(23) of HA schools' teachers.

(b) Of HA schools' teachers, 22,4%(11) indicated that they have a BSc degree versus 6,6%(2) of HD schools' teachers. These responses suggest that HA school teachers may have higher qualifications to teach biology.

(c) Of the HD school teachers, 3,33%(1) and of the HA 18,36%(9), indicated that they have degrees other than science degrees.

(d) Only 6,3%(5), of the teachers did not indicate their highest qualifications.

The analysis of teacher qualifications indicates that although 10%(3) of HD and 4,08%(2) of HA schools' teachers responded that they only have a 2 year diploma it seems as though most biology teachers of both HD and HA schools are qualified to teach biology.

7.2.1.5 Experience in biology teaching

Figure 7.5 is an analysis of the biology teachers of HD and HA schools' responses to the question concerning biology teaching experience. The following can be interpreted from Figure 7.5.

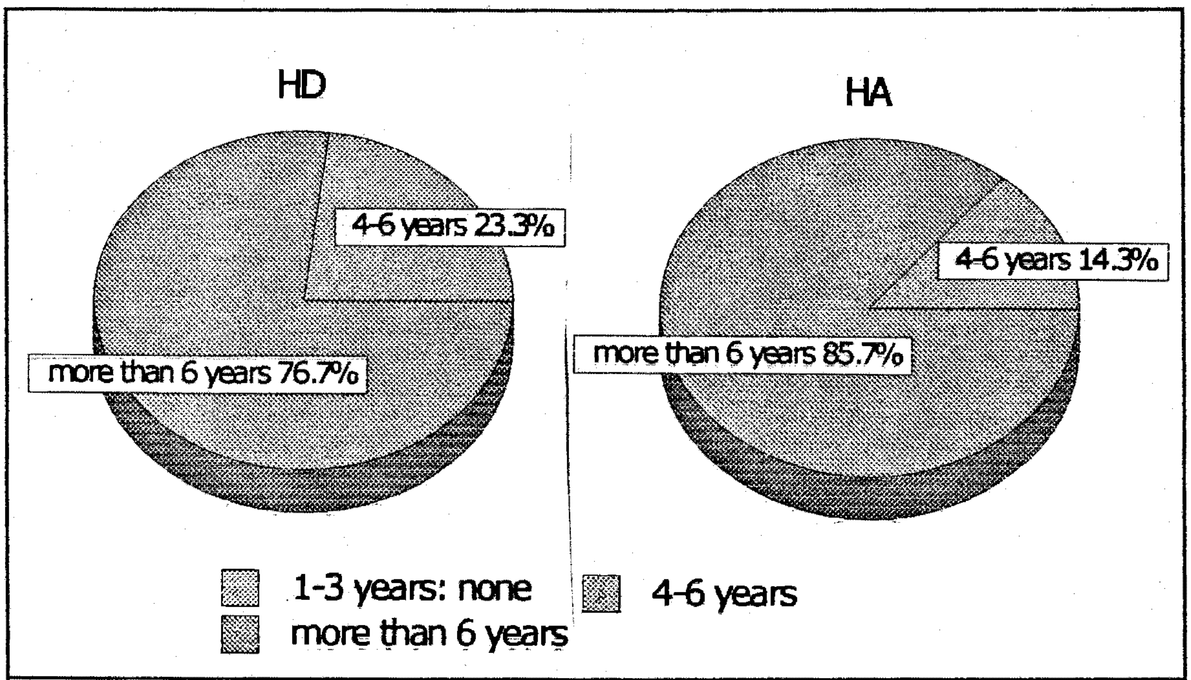
(a) The majority of respondents have a teaching experience of more than six years; 85,70% (HA schools' teachers) and 76,70% (HD schools' teachers).

(b) Of HD schools' teachers, 23,33%(7), and of HA schools' teachers, 14,30%(7) have 4-6 years biology teaching experience. Teachers of HD schools 76,7%(23) indicated that they have more than 6 years teaching experience and of HA schools 85,7%(42).

(c) As indicated in Figure 7.5 teachers from HD and HA schools might not differ significantly as regards their teaching experience (9,04% difference).

(d) It is also interesting to note that no teacher involved in this survey has taught biology for less than 4 years. The reason for this might be that senior biology teachers completed the questionnaires.

Figure 7.5 Biology teaching experience of respondents



HD	HA
n = 30 4-6 years = 7 more than 6 years = 23	n = 49 4-6 years = 7 more than 6 years = 42

When one considers the qualification (vide Figure 7.3 and Figure 7.4) and the teaching experience (vide Figure 7.5) of biology teachers, the majority of biology teachers should be able to implement a process approach, once they have completed well presented, process approach-based methodology courses.

7.2.2 Biology teachers' responses concerning a process approach

Biology teachers were requested to indicate if they know what the following terms mean:

A process approach.
Basic- and integrated process skills.

Teachers had to read the definitions for a process approach and basic- and integrated process skills.

Defining a process approach:

A process approach can be described as a number of processes which the learners use during biology activities (e.g. conducting experiments) to develop intellectual and critical thinking skills in order to have a better understanding of the content and acquire and apply information. A process refers to the fact that the teaching of biology should be in line with what scientists do. That is, gaining information by observing, classifying, predicting, etc. The process approach, therefore, utilises the basic- and integrated process skills.

Basic process skills:

Basic skills can be described as those primary (simpler) skills that a learner develops. These skills are used from pre-primary school up to Grade 5, for example: observation (use the senses to gather information); inference drawing (make an adequate guess about an object or event based on gathered information); classification (grouping or ordering of objects or events into categories based on properties or criteria); communication (use words or graphic symbols to describe an object, action, event); measurement (use measuring instruments e.g. watch, scale, thermometer, etc.); prediction (state of outcome of a future event based on a pattern of evidence) and using numbers.

Integrated process skills:

Integrated process skills are dependent on the learner's ablity to think on a high level and to consider more than one idea at the same time. The term 'integrated' implies that various of the basic process skills can be combined to solve problems. The basic process skills are prerequisites for integrated process skills. Integrated process skills are skills needed to execute scientific experiments. These skills consists of: defining operationally (the ability to express questions in more precise terms, such that the information required is clear); interpreting data (organise data and draw conclusions from it); controlling and manipulating variables (identify variables that can affect an experimental outcome, keeping most variables constant while manipulating only the independent variable); formulating a hypothesis (stating the expected outcome of an experiment) and experimenting (conducting an entire experiment and interpreting the results of the experiment).

7.2.2.1 Knowledge of a process approach

The survey in this research study suggests that a minority of respondents do not know what a process approach is. Of HD schools' teachers 13,33%(4) and of HA schools' teachers 4,18%(2) indicated that they had no idea as to what it entails; 36,67%(11) of HD schools' teachers and 53,07%(26) of HA schools' teachers indicated that they knew what it entailed. Of the HD schools' teachers 50,00%(15) and of the HA schools' teachers 42,85%(21), indicated 'to a limited extent'.

The above analysis reveals that more HA schools' teachers claimed to know what the term process approach meant or have a 'limited' understanding than HD school teachers. The teachers' knowledge of a process approach can be considered as the most important aspect of this research. If teachers do not know what a process approach is, some of them may not be able to implement it. However, this problem was solved telephonically where the researcher explained the meaning of a process approach to some of the teachers.

Table 7.1 Teachers' knowledge of a process approach

	HD SCHOOLS		HA SCHOOLS	
	n	%	n	%
yes	11	36,67%	26	53,07%
to a limited extent	15	50,00%	21	42,85%
not at all	4	13,33%	2	4,18%
Total	30	100,00%	49	100,00%

7.2.2.2 Teachers of HD and HA schools' knowledge of basic- and integrated process skills

The majority of teachers indicated that they know what basic- and integrated process skills are (53,33%[16] from HD schools and 59,20%[29] from HA schools). Of the teachers from HD schools 40%(12) and 40,80%(20) from HA schools, answered 'to a limited extent'. Only 6,67%(2) of the teachers from HD schools answered 'not at all'. Although some teachers of HD and HA schools indicated that they do not know the meaning of a process approach it became clear to the researcher (after numerous phone calls) that respondents knew what process skills were but they were not always familiar with the term 'process approach'. After explaining the meaning of a process approach to those who were unfamiliar with the terminology, the researcher was under the impression that respondents were able to complete the questionnaire. However, 6,67%(2) of HD schools' teachers indicated that they still did not know what basic- and integrated process skills were.

Table 7.2 Teachers' knowledge of basic- and integrated process skills

	HD SCHOOLS		HA SCHOOLS	
	n	%	n	%
yes	16	53,33%	29	59,20%
to a limited extent	12	40,00%	20	40,80%
not at all	2	6,67%	0	0,00%
Total	30	100%	49	100,00%

7.2.3 Characteristics associated with a process approach in biology teaching

7.2.3.1 Reported incidence of various characteristics of a process approach

Some essential characteristics of a process approach were numbered 1-13 and listed in the questionnaire. The purpose was to determine the extent to which teachers use a process approach when teaching biology. Listed below are some of the characteristics associated with a process approach.

Table 7.3 Characteristics associated with a process approach

Characteristics
1. Learners choose an issue or problem to investigate during biology activities
2. Learners do experiments
3. Learners collect their own data during biology activities
4. Learners form their own questions about the world around them
5. Learners do biology projects, which involve proposing a solution to a problem
6. Learners make their own decisions to solve a problem
7. Learners organise data and draw conclusions from it
8. Learners design their own experiments
9. Learners become curious to acquire more information
10. Learners state the expected outcome of an experiment
11. Learners also use biology skills in other disciplines such as: English, art, social studies, and others
12. Learners work with fellow learners to acquire and apply information during investigations (group work)
13. Learners use their writing skills (words, graphs, etc.) to share their biology ideas with fellow learners

Teachers were requested to indicate the extent to which they use the characteristics associated with a process approach in biology teaching. Teachers were to encircle one of the following:

Always
Often
Seldom
Never.

Table 7.4 represents the analyses of all the sampled teachers' responses concerning the extent to which characteristics (1-13) associated with a process approach are used in biology teaching.

Table 7.4 Sampled biology teachers' responses to characteristics 1-13

CHARACTERISTIC	1		2		3		4		5		6		7	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
ALWAYS	4	5,1	14	17,7	12	15,2	7	8,9	8	10,1	12	15,2	20	25,3
OFTEN	32	40,5	44	55,7	37	46,8	32	40,4	43	54,4	41	51,9	44	55,7
SELDOM	30	38,0	15	19,0	26	32,9	33	41,8	22	27,8	20	25,3	11	13,9
NEVER	13	16,4	6	7,6	4	5,1	7	8,9	6	7,7	6	7,6	4	5,1
TOTAL	**79**	**100**	**79**	**100**	**79**	**100**	**79**	**100**	**79**	**100**	**79**	**100**	**79**	**100**

CHARACTERISTIC	8		9		10		11		12		13	
	n	%	n	%	n	%	n	%	n	%	n	%
ALWAYS	0	0	12	15,2	10	12,65	3	3,8	11	13,9	13	16,1
OFTEN	14	17,7	49	62,0	42	53,16	41	52,6	48	60,8	37	46,8
SELDOM	36	45,6	18	22,8	21	26,58	29	37,2	17	21,5	25	32
NEVER	29	36,7	0	0	6	7,61	5	6,4	3	3,8	4	5,1
TOTAL	**79**	**100**	**70**	**100**	**79**	**100**	**79**	**100**	**79**	**100**	**79**	**100**

From the above table it is evident that there is a remarkable difference between the characteristic 'learners design their own experiments' and the others, which will be discussed (vide 7.2.3.2). To illustrate the differences between the different characteristics more clearly, responses will be ranked from highest to lowest for categories 'always' and 'often'.

7.2.3.2. Ranking of possible characteristics of a process approach from highest to lowest

Respondents were required to indicate the extent to which each of the statements related to a process approach, applies to their teaching. The sequence of the statements has been changed, ranking from highest to lowest. 'Seldom' and 'never' are not indicated in Table 7.5 as responses to 'often' and 'always' will reflect to what extent teachers are using the characteristics associated with a process approach.

Table 7.5 Characteristics (1-13) associated with a process approach ranked from highest to lowest

NO	CHARACTERISTIC	ALWAYS		OFTEN		TOTAL	
		n	%	n	%	n	%
1	Learners organise data and draw conclusions from it	20	25,3%	44	55,7%	64	81,0%
2	Learners become curious to acquire more information	12	15,2%	49	62,0%	61	77,2%
3	Learners work with fellow learners to acquire and apply information during investigations (group work)	11	13,9%	48	60,8%	59	74,7%
4	Learners do experiments	14	17,7%	44	55,7%	58	73,4%
5	Learners state the expected outcome of an experiment	10	13,0%	42	54,5%	52	67,5%
6	Learners make their own decisions to solve a problem	12	15,2%	41	51,9%	53	67,1%
7	Learners do biology projects, which involve proposing a solution to a problem	8	10,1%	43	54,5%	51	64,6%
8	Learners use their writing skills (words, graphs, etc.) to share their biology ideas with fellow learners	13	16,1%	37	46,8%	50	63,0%
9	Learners collect their own data during biology activities	12	15,2%	37	46,8%	49	62,0%
10	Learners also use biology skills in other disciplines such as: English, art, social studies, and others	3	3,8%	41	51,9%	44	55,7%
11	Learners form their own questions about the world around them	7	8,9%	32	40,5%	39	49,4%
12	Learners choose an issue or problem to investigate during biology activities	4	5,1%	32	40,5%	36	45,6%
13	Learners design their own experiments	0	0%	14	17,7%	14	17,7%

(a) These responses, as in Table 7.5 ranged from 25,3%(20) for 'always', 55,7%(44) for 'often' for 'learners organise data and draw conclusions from it' to 17,7%(14) for learners 'design their own experiments' 'often' and 0 percent for 'always'.

(b) The possible reason why 'learners organise data and draw conclusions from it' drew the highest percentage, might be the fact that many biology teachers have been introduced to the OBE principles of *Curriculum 2005* or *21* (discussed in 4.4 and 4.5). *Curriculum 2005* or *21* which are learner-centred enable the teacher to create more learning situations where learners can form their own conclusions based on the knowledge they have acquired than when using traditional methods. Another possible reason why the majority of teachers encircled 'often' and 'always' for the characteristic 'learners organise data and draw conclusions from it' might be that they consider this characteristic as the simplest use in their teaching strategies.

(c) It is interesting to note that teachers rarely 17,7%(14) use the teaching strategy 'learners design their own experiments'. This finding will have implications for the implementation of a process approach as the skill of planning and designing experiments is a major component of inquiry activities (Tamir & Amir 1987: 137-143). Roth and Roychoudhury (1993:127-152) found that learners who learn to select research problems, to plan and design experiments might be able to acquire the data necessary to answer questions of their interest. Some of the many possible reasons why teachers are not using the teaching strategy 'learners design their own experiments' might be that teachers either do not know or are not trained on how to create such learning activities or do not have the time to do so. They may not be innovative enough to facilitate learners by making their own practical equipment to do experiments when apparatus are not available.

(d) Two other characteristics associated with a process approach that received second and third lowest percentages were 'learners choose an issue or problem to investigate during biology activities' 40,5%(32) for 'often' and 5,1%(4) for 'always' and 'learners form their own questions about the world around them' which were 40,5%(32) for 'often' and 8,9%(7) for 'always' respectively. The following comments from teachers suggest that they might not always use characteristics associated with a process approach:

'The syllabus is exam-driven and time restricted'

'It is impossible to evaluate sixty learners in one class every biology period'

'There is no guidance for the teacher (sic)'

Teachers indicated that they are not always guided and do not always have time because of the exam-driven syllabus to allow learners to choose an issue or problem to investigate or to form questions about the world around them during biology lessons.

(e) All 13 characteristics also drew responses of 'seldom' and/or 'never'. The percentage of teachers who responded by choosing 'seldom' and/or 'never' ranged from 9%(7) for 'learners organise data and draw conclusions from it' to 82,20%(65) for 'learners design their own experiments' (vide Table 7.4). These percentages re-affirm that the characteristic 'learners design their own experiments' is not always used when teachers teach biology.

As there might be several factors which may prevent teachers from using the characteristics (1-13) associated with a process approach in the classroom, the questionnaires of teachers at HD and HA schools are compared to determine whether they differ and, if so, to what extent.

7.2.3.3 Comparison of ranking between HD and HA schools teachers' responses according to characteristics 1-13 associated with a process approach from highest to lowest (vide Table 7.6).

It is important to compare the responses of HD and HA schools teachers to the 13 characteristics of a process approach as these differences will indicate what teaching strategies teachers are using in the biology classroom. The rank order (highest % to lowest %) of the 13 characteristics for responses 'always' and 'often' for HD and HA schools' teachers varied from each other as shown in Table 7.6. As responses to 'always' and 'often' indicate the characteristic that is used mostly by biology teachers, the researcher used the two for analyses purposes.

Table 7.6 Responses of sampled biology teachers to characteristics (1-13) associated with a process approach ranked from highest to lowest

CHARACTERISTIC	HD SCHOOLS		CHARACTERISTIC	HA SCHOOLS	
	ALWAYS	OFTEN		ALWAYS	OFTEN
Learners become curious to acquire more information	20% 6	60% 18	Learners organise data and draw conclusions from it	16,32% 8	71,41% 35
Learners organise data and draw conclusions from it	40% 12	30% 9	Learners do experiments	8,16% 4	75,51% 37
Learners work with fellow learners to acquire and apply information during investigations (group work)	26,66% 8	43,33% 13	Learners use their writing skills to share their biology ideas with fellow learners	22,44% 11	55,10% 27
Learners do biology projects, which involve proposing a solution to a problem	26,66% 8	36,66% 11	Learners work with fellow learners to acquire and apply information during investigations (group work)	4,08% 2	71,42% 35
Learners state the expected outcome of an experiment	13,33% 4	46,66% 14	Learners become curious to acquire more information	12,24% 6	63,62% 31
Learners make their own decisions to solve a problem	20% 6	36,66% 11	Learners make their own decisions to solve a problem	12,24% 6	61,22% 30
Learners do experiments	33,33% 10	23,33% 7	Learners state the expected outcome of an experiment	12,24% 6	57,14% 28

CHARACTERISTIC	HD SCHOOLS		CHARACTERISTIC	HA SCHOOLS	
	ALWAYS	OFTEN		ALWAYS	OFTEN
Learners collect their own data during biology activities	33,33% 10	23,33% 7	Learners collect their own data during biology activities	4,08% 2	61,22% 30
Learners also use biology skills in other disciplines such as: English, art, social studies, and others	10% 3	36,66% 11	Learners do biology projects, which involve proposing a solution to a problem	0% 0	65,3% 32
Learners use their writing skills to share their biology ideas with fellow learners	6,66% 2	33,33% 10	Learners also use biology skills in other disciplines such as: English, art, social studies, and others	0% 0	61,22% 30
Learners choose an issue or problem to investigate during biology activities	3,33% 1	26,66% 8	Learners form their own questions about the world around them	10,20% 5	46,93% 23
Learners form their own questions about the world around them	6,66% 2	30% 9	Learners choose an issue or problem to investigate during biology activities	6,12% 3	51,02% 25
Learners design their own experiments	0% 0	16,66% 5	Learners design their own experiments	0% 0	18,36% 9

'Learners design their own experiments' was indicated the lowest by HD and HA schools' teachers 16,66%(5) and 18,36%(9). Although only 18,36%(9) of HA schools' teachers indicated that learners frequently design their own experiments, 83,6%(41) affirmed that they do include experiments in their teaching. In contrast, HD schools' learners do not always design their own experiments 56,66%(17). This will have implications for the successful implementation of a process approach, as learners need to be actively involved in the designing and conducting of experiments in the biology classroom (Mossom 1989:120).

When comparing the rank order (vide Table 7.6) responses of teachers at HD and HA schools, the following statements can be made:

(a) Of HD schools 56,66%(17) of the biology teachers indicated that 'learners do experiments' and 83,6%(41) of HA schools' teachers. Teachers commented that some of them do not always do practical work as they do not always know how to execute the experiment, do not have equipment to do so and large classes mostly prevent them to do experiments. The reasons most probably are that teachers lack sufficient training or that they have to be creative and innovative to combat the lack of equipment (De Beer 1995:31 and Slabbert 1997:18). Teachers need to be creative to replace expensive material with simple hand-made apparatus when doing experiments.

A teacher from an HD school comments as follows:

> *'Teachers in formerly 'disadvantaged' schools have neither the confidence nor the infrastructure to do experiments'.*

(b) Another characteristic that was considered differently by teachers at HD and HA schools was 'learners use their writing skills to share their biology ideas with fellow learners'. Of the HA school teachers 77,55%(38) indicated that 'learners use their writing skills to share their biology ideas with fellow learners' 'always and often' in comparison with 40%(12) of HD school teachers.

(c) As the characteristics 'learners work with fellow learners to acquire and apply information during investigations' and 'learners use their writing skills to share their biology ideas with fellow learners' can both be used when doing group work, they could have drawn the same response from every teacher. However, HD schools teachers' responses varied for 'learners use their writing skills to share their biology ideas with fellow learners' from 40%(12) to 69,99%(21) for 'learners work with fellow learners to acquire and apply information during investigations'. The reason for this difference is not clear. Rolheiser and Glickman (1995:196) state that by working with fellow learners, learners develop writing skills necessary for promotive interaction between individuals.

(d) By combining the responses to 'always' and 'often' for the characteristics 'learners organise data and draw conclusions from it' and 'learners work with fellow learners to acquire and apply information during investigations' it is apparent that both characteristics are considered applicable by HD and HA schools' teachers (70%[21] and 87,75%[43] respectively).

(e) Although the characteristic 'learners work with fellow learners to acquire and apply information during investigations' was indicated by HD (69,99%[19] and HA (75,5%[37]) schools' teachers to hapen 'often' in their classrooms, this characteristic drew numerous negative comments such as:

'In group work a child relies on others to pull them through the work. Eventually this child has to face an exam situation on his/her own - be it end of Grade 9 (junior school certification or in Grade 12). This child who relies on others, in the group to help him does not learn to work independently and to solve problems in a situation.'

'Group work is not enjoyed by learners - good learners do not want to share their knowledge and hard work with other learners who do not contribute and do the minimum of work.'

'Group work is not always the solution for the 'brighter' learners who have to lead and give all the time.'

'Group work does not suit everyone and no-one works in a group all the time - individual work is required.'

'Group work is a crutch for most students.'

'There is no time to help weaker learners in the group or extend gifted learners.'

'I find it difficult to assess them if they work in groups.'

The comparison between HD and HA schools teachers' responses to characteristics 1-13 of a process approach is important to determine whether teachers are using some of the characteristics associated with the approach when teaching biology. The analysis and ranking of characteristics suggest that the teaching strategies of teachers at HA and HD schools differ. According to the comments of sampled teachers from HA schools, more of them use biology teaching strategies containing the characteristics of a process approach than teachers from

HD schools. The reasons for using different teaching strategies will have to be determined in order to ensure the successful implementation of a process approach. Therefore, the responses of teachers concerning the factors that could affect attempts at using a process approach, will be analysed in 7.2.5.

7.2.4 Teachers' responses concerning the frequency in doing inquiry activities

Biology teachers were requested to indicate how frequently they do inquiry activities (for example: fieldwork, certain practical work and project work) when teaching biology.

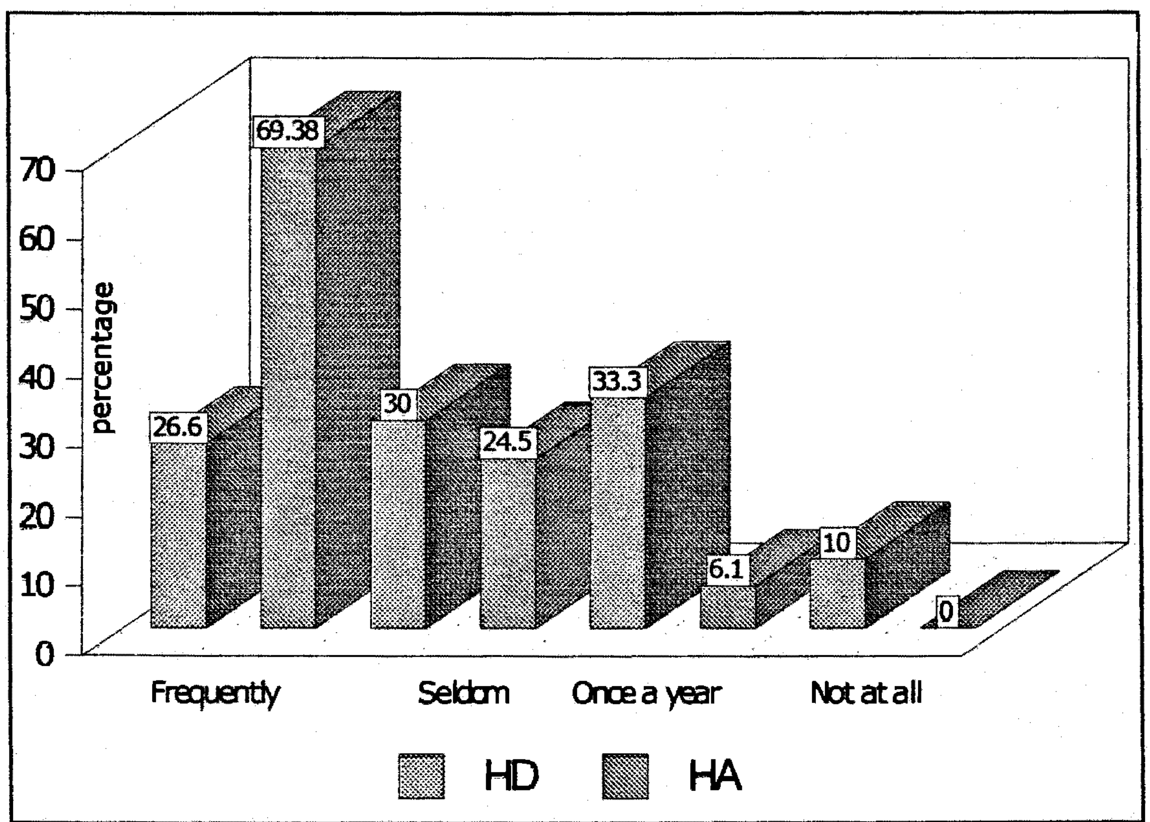
The analysis of responses indicated the following:

Frequently (once a week):	53,2% (42)
Seldom (once a month):	26,6% (21)
Once a year:	16,5% (13)
Not at all:	3,7% (3)

The fact that 53,2%(42) indicated that they allow their learners to do inquiry activities 'frequently' is contrary to the findings of De Beer and Van Rooyen (1990:54); Du Toit (1994:6-8) and Slabbert (1992:35) who assert that teachers are mostly concentrating on the lecture and textbook methods rather than using inquiry activities such as practical work, field work and project work. This may suggest that some teachers have changed their teaching strategies to more inquiry activities.

The researcher compared the answers of teachers at HD and HA schools as to the frequency they do inquiry activities. This comparison is set out graphically in Figure 7.6.

Figure 7.6 The frequency of inquiry activities in HD and HA schools



HD	**HA**
n = 30 Frequently = 8 Seldom = 9 Once a year = 10 Not at all = 3	n = 49 Frequently = 34 Seldom = 12 Once a year = 3 Not at all = 0

Responses of teachers at HD and HA schools differ to a great extent. Only 26,6%(8) of HD school teachers claimed to be using inquiry activities frequently when teaching biology in contrast with 69,38%(34) of HA school teachers. As inquiry activities may enable learners to develop critical thinking skills, that is a characteristic of a process approach, it is important to consider teachers' comments on these activities. Of the 46,8%(37) comments received from HA schools' teachers on inquiry activities the following comments were drawn which require attention.

> *'Learners seem to be reluctant to think independently and depend merely on rote learning - which I feel gives them a sense of security. To inquire and discover can be intimidating.'*

'Inquiring activities force pupils to start thinking for themselves and to apply knowledge to varying situations which will help eliminate parrot repetition or regurgitated facts.'

'Learners enjoy practicals/field work more and are enthusiastic and motivated - they then seek further knowledge of their own accord, bringing this information to share with the class.'

'Discovery learning is the fore-runner of a process approach.'

'Biology is an excellent example of a subject where a process approach can be used with great success. Practical applications, discovery experiency (experiments), interpreting data etc.'

'To teach through inquiry rather than regurgitation the subject taught has meaning and the learner gains benefit.'

In Chapter Five (vide 5.4.2) it was pointed out that the major aim of providing inquiry activities by the biology teacher is to develop problem-solving skills in a methodical scientific manner. Learners should practice being biologists in order to fully understand the living world. It is evident in Figure 7.6 that HD schools' teachers do not always use inquiry activities nor do HA schools' teachers. The reason for this most probably lies within the excuses of teachers namely, lack of equipment and inadequate resource material. These factors all received high percentages (vide Table 7.8).

7.2.5 Teachers' responses concerning factors that could adversely affect attempts at using a process approach in biology teaching

Twenty seven factors that could affect the use of a process approach when teachers teach biology, were listed in the teacher questionnaire (see Appendix A2).

Table 7.7 Factors that could affect the biology teacher's use to a process approach

1	A lengthy syllabus
2	Large classes
3	Lack of equipment
4	Inadequate resource material
5	The need to produce good exam results
6	The discipline factor (noisy classes)
7	Mixed ability classes (different learning abilities of learners)
8	Inflexible syllabi (no space or time for teachers' own innovative ideas)
9	Additional 'demands on teacher' (e.g. increased workload, more lesson planning etc.)
10	Teachers' qualifications (e.g. biology I, biology II, biology III etc.)
11	Attitude of the teacher
12	Lack of opportunities for teachers to attend workshops
13	Irrelevant content (content is not relevant to all learners' different cultural backgrounds)
14	Insufficient integration of biology with other subjects
15	Not enough assistance from parents to develop learners' process skills
16	The language barrier (e.g. English for N-Sotho learners) hampers the development of learners' process skills
17	Insufficient infrastructure (e.g. electricity, desks, water etc)
18	Outcomes for a process approach are not clearly stated by the curricula developers.
19	Teachers lack knowledge of teaching/learning strategies which promote the development of process skills
20	Learners' reliance on mere memorisation of facts (rather than using skills to acquire information)

21	Insufficient lesson planning of biology teachers
22	Learner group work is neglected
23	Teacher-centred teaching
24	Teachers avoid inquiry activities such as field work/laboratory work & practical work
25	Learners fail to apply biology content to everyday life situations
26	Teachers do not create opportunities where learners can interact with instructional material (e.g. conduct experiments as biologists do)
27	The principal fails to provide a supportive climate in your school to implement a process approach

The biology teachers were requested to indicate the extent to which these factors may affect attempts at using a process approach as a teaching strategy in secondary biology education. The following scale was used:

To a great extent ← scale → Not at all

1 2 3 4 5 6

Table 7.8 represents the responses of teachers from HA and HD schools. 'To a great extent' is indicated by combining 1 and 2 on the scale while, 'not at all' is indicated by combining 5 and 6 on the scale. Percentages are used to indicate the extent these listed factors may affect the implementation of a process approach.

Table 7.8 Teachers' responses to the listed factors that could affect the use of a process approach by biology teachers

	FACTORS	HD SCHOOLS n = 30			HA SCHOOLS n = 49		
		To a great extent		Not at all	To a great extent		Not at all
		1 + 2	3 + 4	5 + 6	1 + 2	3 + 4	5 + 6
1	A lengthy syllabus	80% 24	13,33% 4	6,66% 2	65,30% 32	20,4% 10	10,20% 5
2	Large classes	93,33% 28	3,33% 1	3,33% 1	77,55% 38	18,36% 9	4,08% 2
3	Lack of equipment	76,66% 23	13,33% 4	10,00% 3	44,89% 22	36,73% 18	18,36% 9
4	Inadequate resource material	73,33% 22	23,33% 7	3,33% 1	36,7% 18	40,81% 20	22,44% 11
5	The need to produce good exam results	60% 18	26,66% 8	13,33% 4	51,0% 25	28,57% 14	20,40% 10
6	The discipline factor (noisy classes)	26,66% 8	36,66% 11	36,66% 11	34,69% 17	36,73% 18	28,57% 14
7	Mixed ability classes (different learning abilities)	36,66% 11	26,66% 8	36,66% 11	51,02% 25	40,08% 20	8,16% 4
8	Inflexible syllabi (no space or time for teachers' own innovative ideas)	56,66% 17	26,66% 8	16,66% 5	44,89% 22	30,61% 15	24,48% 12
9	Additional 'demands' on teachers (e.g. increased workload, more lesson planning etc.)	66,66% 20	20% 6	13,33% 4	67,34% 33	28,57% 14	4,08% 2
10	Teachers' qualifications (e.g. biology I; biology II; biology III etc.)	40% 12	26,66% 8	33,33% 10	30,61% 15	30,6% 15	38,77% 19
11	Attitude of the teacher	63,33% 19	16,66% 5	20,0% 6	67,34% 33	10,20% 5	22,44% 11

	FACTORS	HD SCHOOLS n = 30			HA SCHOOLS n = 49		
		To a great extent		Not at all	To a great extent		Not at all
		1 + 2	3 + 4	5 + 6	1 + 2	3 + 4	5 + 6
12	Lack of opportunities for teachers to attend workshops	50% 15	33,33% 10	16,66% 5	34,69% 17	53,06% 26	12,24% 6
13	Irrelevant content (content is not relevant to all learners' different cultural backgrounds)	50% 15	23,33% 7	26,66% 8	38,77% 19	42,85% 21	18,36% 9
14	Insufficient integration of biology with other subjects	40% 12	36,66% 11	23,33% 7	32,65% 16	44,89% 22	22,44% 11
15	Not enough assistance from parents to develop learners' process skills	43,3% 13	23,33% 7	33,33% 10	36,73% 18	32,65% 16	30,61% 15
16	The language barrier (e.g. English for N-Sotho learners) hampers the development of learners' process skills	46,66% 14	20% 6	33,33% 10	32,65% 16	46,93% 23	20,40% 10
17	Insufficient infrastructure (e.g. electricity, desks, water etc.)	50% 15	30% 9	20,0% 6	20,40% 10	26,53% 13	53,06% 25
18	Outcomes for a process approach are not clearly stated by the curricula developers.	60% 18	23,33% 7	16,66% 5	53,06% 26	32,65% 16	14,28% 7

	FACTORS	HD SCHOOLS n = 30			HA SCHOOLS n = 49		
		To a great extent		Not at all	To a great extent		Not at all
		1 + 2	3 + 4	5 + 6	1 + 2	3 + 4	5 + 6
19	Teachers' lack of knowledge of teaching/learning strategies which promote the development of process skills	63,33% 19	13,33% 4	23,33% 7	46,93% 23	51,02% 25	2,04% 1
20	Learners' reliance on mere memorisation of facts (rather than using skills to acquire information)	43,33% 13	26,66% 8	30,00% 9	48,97% 24	28,57% 14	22,44% 11
21	Insufficient lesson planning of biology teachers	66,66% 20	26,66% 8	6,66% 2	61,22% 30	14,28% 7	24,48% 12
22	Learner group work is neglected	73,33% 22	20% 6	6,66% 2	59,18% 29	30,61% 15	10,20% 5
23	Teacher-centred teaching	80% 24	16,66% 5	3,33% 1	65,30% 32	22,44% 11	12,24% 6
24	Teachers avoid inquiry activities such as field work/ laboratory work & practical work	86,6% 26	6,66% 2	6,66% 2	63,26% 31	20,4% 10	12,24% 6
25	Learners fail to apply biology content to everyday life situations	76,66% 23	13,33% 4	10% 3	42,85% 21	20,4% 10	16,32% 8
26	Teachers do not create opportunities where learners can interact with instructional material (e.g. conduct experiments as biologists do)	76,66% 23	20% 6	3,33% 1	40,81% 20	44,89% 22	14,28% 7

	FACTORS	HD SCHOOLS n = 30			HA SCHOOLS n = 49		
		To a great extent		Not at all	To a great extent		Not at all
		1 + 2	3 + 4	5 + 6	1 + 2	3 + 4	5 + 6
27	The principal fails to provide a supportive climate in your school to implement a process approach	66,66% 20	20% 6	6,66% 2	38,77% 19	36,73% 18	24,48% 12

These responses reveal some similarities as regards 'to a great extent', namely,

- 'additional demands on teachers' (HD schools' teachers responded 66,66%[20] and HA schools' teachers 67,34%[33]);
- 'attitude of the teacher' (HD schools' teachers responded 63,33%[19] and HA schools' teachers 67,34%[33]);
- 'learners' reliance on mere memorisation of facts' was indicated (HD schools' teachers responded 43,33%[13] and HA schools' teachers 48,97%[24]) and
- 'insufficient lesson planning of biology teachers' 66,66%(20) HD schools' teachers indicated 'to a great extent' and HA schools' teachers 61,22%(30).

In addition, there are also interesting dichotomies from teachers within each category of school namely 33,33%(10) of HD teachers commented that the use of a process approach is 'not at all' influenced by teachers' qualifications and 40%(12)of HD teachers say this factor has a strong influence. The discipline factor is regarded by 26,66%(8) of HD schools' teachers as a negative factor while 36,66%(11) of HD schools' teachers do not regard the discipline factor as problematic. Of HD schools' teachers 36,66%(11) experience mixed ability classes as a negative factor towards the implementation of a process approach while 36,66%(11) of HD schools' teachers indicated that they are 'not at all' influenced by mixed ability classes. Two thirds of the HD schools' teachers (66,66%[20]) indicated that failure of the principal to provide a supportive climate in school to implement a process approach influences the successful implementation of the approach in contradiction with only 38,77%(19) of HA schools' teachers.

The 'language barrier' shared dichotomies of both HD (46,66%[14] for 'to a great extent' and 33,3%[10] for 'not at all') and HA schools' teachers (32,65%[16] for 'to a great extent' and 20,40%[10] for 'not at all').

Of HD schools' teachers, 43,3%(13) indicated that 'not enough assistance from parents to develop learners' process skills' influences the implementation of a process approach 'to a great extent' while 33,33%(10) of HD schools' teachers are not influenced by parent assistance. Of HA schools' teachers 36,73%(18) responded 'to a great extent' while 30,61%(15) of HA schools' teachers indicated 'not at all'.

It is evident that teachers were of the opinion that all 27 listed factors could adversely affect attempts to use a process approach to a great extent in secondary biology teaching. The factor 'large classes', ranged from 93,33%(28) for HD schools' teachers, to 77,55%(38) for HA schools' teachers. It is interesting to note that only 6,66%(2) of HD schools' teachers indicated that lesson planning is 'not at all' affecting them while 24,48%(12) of HA schools' teachers responded 'not at all'. In the following sub-division (vide 7.2.5.1) factors that influence the implementation of a process approach negatively will be ranked from highest to lowest and discussed intensively.

7.2.5.1 Ranking factors (1-27) from highest to lowest to indicate the factors that might influence the implementation of a process approach

The rank order of the 27 listed factors varied for HD and HA schools as indicated in Table 7.9 below. This implies that HD and HA schools' teachers are not affected by the same factors when using a process approach.

The HD schools' teachers indicated that certain factors influenced them to a greater extent than the HA teachers when perceiving the high percentages for factors 'a lengthy syllabus' 80%(24); 'large classes' 93,33%(28); 'lack of equipment' 76,66%(23); 'inadequate resource material' 73,33%(22); 'learner group work is neglected' 73,33%(22); 'teacher-centred teaching' 80%(24) and 'teachers avoid inquiring activities such as field work/laboratory work and practical work' 86,6%(26).

It is therefore important to rank the factors that adversely affect attempts to implement a process approach, and to compare HD and HA schools with regard to these factors.

Table 7.9 Possible factors that might influence the use of a process approach were ranked from the highest to lowest (1-27)

	HD SCHOOLS n = 30	HA SCHOOLS n = 49
	To a great extent	To a great extent
1	Large classes 93,33%(28)	Large classes 77,55%(38)
2	Teachers avoid inquiry activities such as field work/ laboratory work & practical work 86,6%(26)	Additional 'demands' on teachers (e.g. increased workload, more lesson planning etc.) 67,34%(33)
		Attitude of the teacher 67,34%(33)
3	A lengthy syllabus 80%(24)	A lengthy syllabus 65,30%(32)
	Teacher-centred teaching 80%(24)	Teacher-centred teaching 65,30%(32)

	HD SCHOOLS n = 30	HA SCHOOLS n = 49
	To a great extent	To a great extent
4	Lack of equipment 76,66%(23)	Teachers avoid inquiry activities such as field work/laboratory work & practical work 63,26%(31)
	Learners failing to apply biology content to everyday life situations 76,66%(23)	
	Teachers do not create opportunities where learners can interact with instructional material 76,66%(23)	
5	Inadequate resource material 73,33%(22)	Insufficient lesson planning of biology teachers 61,22%(30)
	Learner group work is neglected 22(73,33%)	
6	Additional 'demands' on teachers (e.g. increased workload, more lesson planning etc.) 66,66%(20)	Outcomes for a process approach are not clearly stated by the curricula developers. 53,06%(26)
	Insufficient lesson planning of biology teachers 66,66%(20)	
	The principal fails to provide a supportive climate in your school to implement a process approach 66,66%(20)	
7	Attitude of the teacher 63,33%(19)	The need to produce good exam results 51,0%(25)
	Teachers' lack of knowledge of teaching/learning strategies which promote the development of process skills 63,33%(19)	Mixed ability classes (different learning abilities of learners) 51,0%(25)

	HD SCHOOLS n = 30	HA SCHOOLS n = 49
	To a great extent	To a great extent
8	The need to produce good exam results 60%(18) Outcomes for a process approach are not clearly stated by the curricula developers. 60%(18)	Learners' reliance on mere memorisation of facts (rather than using skills to acquire information) 48,97%(24)
9	Inflexible syllabi (no space or time for teachers' own innovative ideas) 56,66%(17)	Teachers' lack of knowledge of teaching/learning strategies which promote the development of process skills 46,93%(23)
10	Lack of opportunities for teachers to attend workshops 50%(15)	Lack of equipment 44,89%(22)
	Irrelevant content (content is not relevant to all learners' different cultural backgrounds) 50%(15) Insufficient infrastructure (e.g. electricity, desks, water etc) 50%(15)	Inflexible syllabi (no space or time for teachers' own innovative ideas) 44,89%(22)
11	The language barrier (e.g. English for N-Sotho learners) hampers the development of learners' process skills 46,66%(14)	
12	Not enough assistance from parents to develop learners' process skills 43,3%(13) Learners' reliance on mere memorisation of facts (rather than using skills to acquire information) 43,3%(13)	Learners fail to apply biology content to everyday life situations 42,85%(21)

	HD SCHOOLS n = 30	HA SCHOOLS n = 49
	To a great extent	To a great extent
13	Teachers' qualifications (e.g. biology I, biology II, biology III etc.) 40%(12) Insufficient integration of biology with other subjects 40%(12)	Teachers do not create opportunities where learners can interact with instructional material (e.g. conduct experiments as biologists do) 40,81%(20)
14	Mixed ability classes (different learning abilities of learners) 36,66%(11)	Irrelevant content (content is not relevant to all learners' different cultural backgrounds) 38,77%(19) The principal fails to provide a supportive climate in your school to implement a process approach 38,77%(19)
15	The discipline factor (noisy classes) 26,66%(8)	Inadequate resource material 36,65%(18) Not enough assistance from parents to develop learners' process skills 36,65%(18)
16		The discipline factor (noisy classes) 34,69%(17) Lack of opportunities for teachers to attend workshops 34,69%(17)
17		Insufficient integration of biology with other subjects 32,65%(16) The language barrier (e.g. English for N-Sotho learners) hampers the development of learners' process skills 32,65%(16)
18		Teachers' qualifications (e.g. biology I, biology II, biology III etc.) 30,61%(15)

	HD SCHOOLS n = 30	HA SCHOOLS n = 49
	To a great extent	To a great extent
19		Insufficient infrastructure (e.g. electricity, desks, water etc) 20,40%(10)

Table 7.9 illustrates the following:

'Large classes' appear to be the greatest limiting factor for both HD 93,73%(28) and HA schools 77,55%(38). This coincides with the 1990 report of the American Association for the Advancement of Science (AAAS) 'large classes are a barrier to effective teaching'. To develop learners' process skills, to create an environment in which learners can ask questions and debate issues to accommodate various learners' abilities by using various teaching methods and to assess student learning in a variety of ways, small classes are essential (Gotfried, Hoots, Creek, Tampari, Lord & Sines 1993:340-345).

De Beer (1993) conducted a research study on why teachers are not doing practical work in biology. According to his research on HD schools 22,8 percent of the biology teachers indicated that they have an average of 50-60 learners in one class and 18,2 percent indicated they have 41-49 learners per class. These numbers are still increasing every year because of the limited budget for education. Thus teachers will have to cope with large classes when doing practical work as well as educational changes.

The following possible reasons as to why 'large classes' can be considered the most important factor that influences the successful implementation of a process approach, were offered by teachers.

'Large classes prevent teachers from doing practical work, field work and engage learners in inquiring activities.'

'As classes are too big I do not have time to discipline learners and organise them in groups.'

'It is difficult and time consuming to assess learners in large classes.'

These comments from teachers of both HD and HA schools suggest that it is frequently difficult to maintain discipline in a large class. Many teachers do not always conduct practical work as it may lead to a breakdown in class discipline. These comments are in contradiction with Table 7.8 where only a small percentage of HD 26,66%(8) and HA 34,69%(17) schools' teachers indicated the discipline factor. The implementation of *Curriculum 2005* or *21* emphasises regular individual assessment, which is impossible with large classes. That is most probably why so many teachers indicated that 'large classes' prevent the successful implementation of a process approach. The problem of 'large classes' will not change in the foreseeable future as learner numbers are still growing every year and the ratio learners per teacher is increasing (Steyn 1998:187).

The factor 'teachers avoid inquiring activities such as field work / laboratory work and practical work' drew the second highest 86,6%(26) response of HD school teachers and fourth highest 63,26%(31) of HA school teachers. The reasons for these responses can most probably be related to the high responses for 'large classes', and 'a lengthy syllabus' for both HD and HA schools' teachers while the 'lack of equipment', and 'inadequate resource material' are more specific for HD schools. Teachers of HD and HA schools commented on large classes, fieldtrips, inquiry activities, and lengthy syllabus as follows:

HD schools teachers' comments:

'There is no money to take learners on field trips'.

'Our school does not have a laboratory to do inquiry activities and develop skills'.

'I fully believe that inquiry activities such as practical work and field work are vital but it is difficult to implement because of large classes, the time factor and the lengthy syllabus'.

Another reason why teachers are avoiding inquiry activities might be that teachers are not trained to create inquiry learning activities. Van Staden (2000:*pers. comm.*) comments that inquiry activities are not always easily applied in actual teaching/learning as teachers might not be trained to do so. They may have theoretical knowledge but not always sufficient practical application abilities.

If teachers are not able to do inquiry activities, where learners can experiment and discover information, group work might be neglected and learners will have limited opportunities to interact with instructional material to discover for themselves. HD schools' teachers may also find it difficult to create inquiry activities because of a lack of equipment 76,6%(23) and inadequate resource material 73,33%(22).

Thus the neglect of inquiry activities is aggravated by the lack of properly equipped laboratories and suitably qualified teachers. Inquiry activities receive a low priority in HD schools (vide Figure 7.6).

Of HD schools' teachers, 76,66%(23) indicated that biology education is not providing opportunities for learners to apply biology content to every-day life situations. This response is in agreement with Hurd, Bybee, Kahle and Yager (1980:388); Heller (1993:645) and Wilbur (1986:78) who point out that todays' learning activities are emphasising basic acquisition of knowledge to the exclusion of practical application of this knowledge in everyday life. Learners need to develop process skills that will enable them to learn for life.

According to the percentages (vide Table 7.9) responses 'to a great extent' to other factors such as 'additional demands on teachers', (66,66%[20] for HD schools' teachers and 67,34%[33] for HA schools' teachers) 'insufficient lesson planning of biology teachers' (66,66%[20] for HD schools' teachers and 61,22%[30] for HA schools' teachers) and 'attitude of the teacher' (63,33%[19] for HD schools' teachers and 67,34%[33] for HA schools' teachers), the responses for HD and HA schools' teachers were similar (varying from 61,22% to 67,34%). Thus both HD and HA schools' teachers are affected by these factors to a 'great extent'.

The following comments were written by three teachers from HA schools for two of the factors:

'Insufficient lesson planning of biology teachers' (factor number 21)

> *'Inquiry activities where teachers make use of group work cannot work if his/her planning is insufficient.'*

'Additional demands on teachers' (factor number 9)

> *'Teachers do not have the time to apply and prepare for the implementation of a process approach.'*

> *'Busy sport programmes - do not have time for field excursions and workshops after school.'*

Teachers' workload is increasing as teacher numbers are decreasing every year. Apart from changing to a new education system with *Curriculum 2005* or *21*, teachers are also burdened with extra mural activities and workshops after school, leaving little time for sufficient lesson planning. As teachers are not always able to cope with all the changes and extra activities after school, a negative attitude might develop towards any new education approach.

According to Pinnell (1989:99-117) and Dreher (1990:49-64) educators interested in promoting a new approach in biology education may find themselves working with teachers who have less favourable attitudes towards the new approach. Teachers with negative attitudes might prevent the successful implementation of such an approach.

Teachers who are not adequately trained to develop learners' process skills might also reflect a negative attitude to the implementation of a process approach as they are not able to create exciting and interesting learning opportunities where learners can develop process skills.

When reading through the comments of biology teachers, it is apparent that teachers are battling to work through lengthy syllabuses with the final examination in mind.

'The syllabus is rigid with a lot of information which is totally useless to learners in later life.'

'Time and a lengthy syllabus are the two most important restrictions in biology education.'

'The length and content of the syllabus influence the implementation of a process approach to a great extent.'

'A process approach should be guided by a syllabus, a syllabus gives direction how to work.' (sic)

'The biology curriculum is results orientated (distinctions) placing a lot of pressure on the teacher.'

'A lengthy syllabus causes you to fly through the work. There is not a lot of time for practical work and the learners do not want a practical exam, this causes the biology teacher not to do practical work but only demonstrations.' (sic)

'A process approach is the right way to go about but then our syllabus should change.'

From the comments above it is clear that a lengthy syllabus and time both hamper the effective implementation of a process approach in biology education.

The sampled HD (80%[24]) and HA (65,30%[32]) schools' teachers also indicated that teacher-centred teaching prevents the successful implementation of a process approach 'to a great extent'. Hickman and Kennedy (1989:741) and Spady (1992:67-72) state that instructional situations should be learner-centred rather than teacher-centred, leading more to the generation of new questions than to the discovery of some single 'correct answer'.

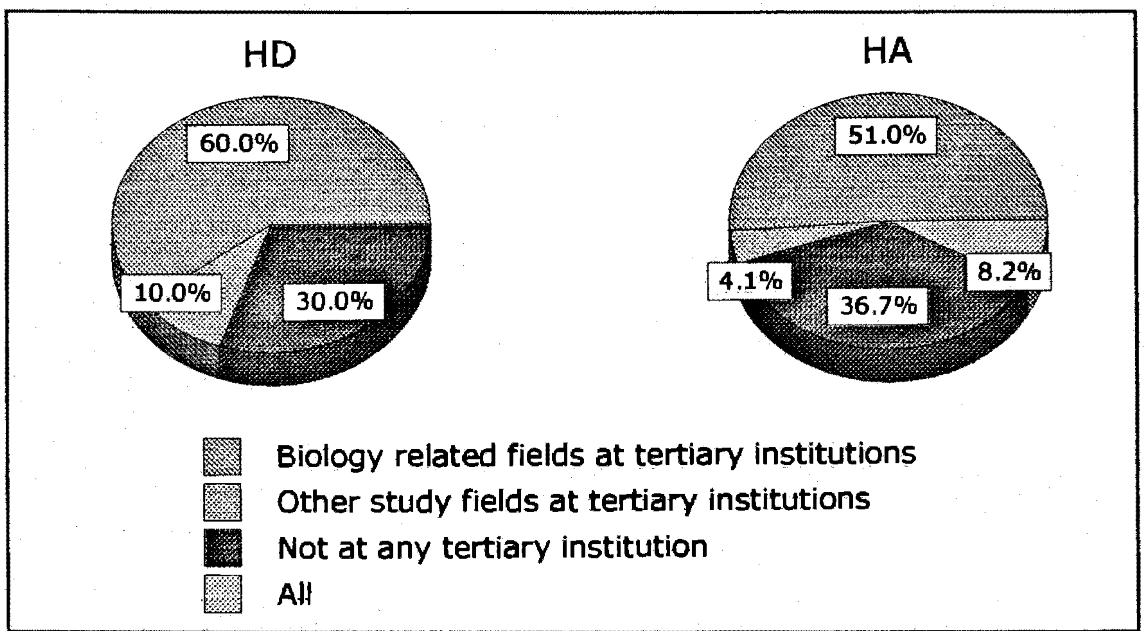
In this research it was important to determine the negative factors in HD and HA schools that can prevent the successful implementation of a process approach. These factors that were identified and discussed in 7.2.5, need due consideration before changes in biology education can take place.

7.2.6 Teachers' responses concerning the value of the development of process skills for learners

Figure 7.7 illustrates the responses of teachers at HD and HA schools to the question ... 'For which target group is the development of process skills the MOST valuable?'

- For those learners who are going to study in biology related fields at tertiary institutions e.g. medicine, biology teaching, engineering.
- For those learners who are going to study in fields other than biology at tertiary institutions e.g. law, commerce.
- For those learners who are not going to study at tertiary institutions.
- All three options.

Figure 7.7 Responses of teachers at HD and HA schools with regard to the target group for whom the development of process skills is the most valuable



HD	**HA**
n = 30 Biology related fields at tertiary institutions = 18 Other study fields at tertiary institutions = 3 Not at any tertiary institution =9 All = 0	n = 49 Biology related fields at tertiary institutions = 25 Other study fields at tertiary institutions = 2 Not at any tertiary institution =18 All = 4

Of teachers from the HD schools 60%(18) and from HA schools' teachers 51,0%(25), indicated that the development of process skills is the most valuable to learners who are going to study in biology-related fields at tertiary institutions. Those teachers may be of the opinion that the development of process skills to acquire knowledge and solve problems is only necessary for those learners who will further their studies in a biology related field at a tertiary institution.

The responses of the HD schools' teachers 30%(9) and HA schools' teachers 36,7%(18) are in contradiction with Knamiller (1984:60), Pepper (1995:1-10) and Spargo (1995b:30-31) who argue that the majority of learners are not destined to become future biologists and that biology programmes should be designed to serve the needs of that large group of matriculants who will not further their studies at tertiary level in a scientific related field.

As the development of a scientific literate nation is crucial for South Africa's survival (Spargo 1995b:30-31), learners who will not further their studies at tertiary institutions will in fact gain the MOST benefit from developing process skills that will enable them to make critical decisions and learn for life.

7.3 SUMMARY

Questionnaires were sent to a small sample of biology teachers of HD and HA schools in Gauteng Province to determine possible reasons why a process approach might not be successfully implemented in secondary biology education.

Ninety eight questionnaires were despatched to teachers. Seventy nine of the questionnaires despatched to teachers were completed and returned representing an overall return of 80,60%.

The ratio of males:females in the research study differ for HD schools (43,57:56,7) and HA schools (12,3:87,7). The majority of teachers who completed the questionnaire were level one teachers (HD schools = 63,33%[19] and HA schools = 53,1%[26]). An analysis of the academic qualifications of HD and HA schools' teachers indicates that HA schools' teachers might be better qualified. Of the HA schools' teachers, 22,44%(11) indicated that they have BSc degrees and 18,36%(9) other degrees versus the 6,66%(2) (BSc degrees) and 3,33%(1) (other degrees) of HD schools' teachers. Of all teachers 86,92 percent are qualified to teach biology. Ten percent (3) of HD schools' teachers and 4,08%(2) of HA schools' teachers have a 2 year diploma.

The survey in this research study requested teachers to indicate the extent to which they use the listed characteristics (1-13) associated with a process approach in biology teaching. The responses ranged from 'learners organise data and draw conclusions from it' (81,0%) to 'learners design their own experiments' (17,7%). There was a marked difference between responses of HD 56,66%(17) and HA 83,61%(41) schools' teachers for the characteristic 'learners do experiments'.

According to Slabbert (2000:*pers. comm.*) the reason for this might be that teachers lack equipment and sufficient training to counter equipment problems.

Only 26,6%(8) of HD schools' teachers indicated that they use inquiry activities 'frequently' in biology education. Of the HA schools' teachers 69,38%(34) responded that they frequently use inquiry activities. The reasons why HD schools' teachers do not frequently use inquiry activities may be related to negative factors which were indicated namely: 'lack of equipment', 'large classes' and 'inadequate resource material'(vide Table 7.9).

Although most of the sampled teachers were of the opinion that all 27 factors could adversely affect the implementation of a process approach 'to a great extent', there were some teachers who responded differently to a few factors. Of the factors teachers indicated 'large classes' as the most frequently cited to implementing a process approach. The reason for this response is most probably that it is difficult to assess learners in large groups.

Responses of HA and HD schools' teachers for factors such as 'additional demands on teachers'; 'insufficient lesson planning of biology teachers' and 'attitude of the teacher' were similar. Some of the sampled teachers indicated that they are burdened with extra activities after school and still have to cope with sufficient lesson planning for large classes in order to change to the new outcomes based system (*Curriculum 2005* or *21*). All these additional demands on teachers might cause them to develop a negative attitude towards any change. A negative attitude could hamper the successful implementation of a process approach.

With regard to a process approach as a teaching strategy for biology education, most of the sampled teachers (HD schools 60%[18] and HA schools 51%[25]) indicated that this teaching approach would be the MOST valuable to those learners who are going to study in science related fields at tertiary institutions.

CHAPTER EIGHT

FINDINGS OF INTERVIEWS

8.1 INTRODUCTION

The responses of interviews conducted with subject- and education specialists will be presented and analysed in this chapter. These responses can be valuable for gathering information in areas where a deep understanding is needed and where probing might be required.

Structured questions (vide Table 8.1) were asked on which interviewees elaborated, by giving their individual opinions on why a process approach may not be successfully implemented in biology education.

8.2 FINDINGS OF INTERVIEWS' SURVEY

Subject-, education- and OBE specialists from a college (Soweto College of Education) a technikon (Technikon North Gauteng) different universities (University of Pretoria, University of South Africa, University of Australia and VISTA University) and the Education Department were interviewed. These interviews enabled the researcher to collect information on possible reasons why a process approach is not successfully implemented, which was in turn used in a qualitative manner to yield findings reported in this study.

8.2.1 Analysis of interviewees' responses

As interviews are very long and repetition of answers sometimes occurs, the researcher selected only those comments that will be valuable for this research. Some of the interviewees requested that not all of their answers be quoted. Therefore, the interviewees names were not indicated next to the comments. Some of the comments which are allowed to be quoted, have been referred to in the literature study and will be referred to in the recommendations of this research.

Table 8.1 reflects the open-ended structured questions that were asked during the interviews.

Table 8.1 Interview questions

	Questions
1.	Are the current biology curricula flexible and relevant to address the needs of South African citizens?
2.	What approach should be used to teach biology effectively? (with the development of learners' process skills in mind)
3.	If one considers a process approach (development of process skills) as important to teach biology effectively, why is this approach not implemented successfully in biology education?
4.	How can the factors that might hamper the effective implementation of a process approach be combated?
5.	Which methods should be used to develop learners' process skills?
6.	Are teachers adequately trained to implement a process approach?

Question 1

Are the current biology curricula flexible and relevant to address the needs of South African citizens?

Of the 19 interviewees 84,2%(16) most of them were of the opinion that biology curricula do not address the needs of the community. The biology curricula do not always consider the cultural background of the various population groups in South Africa and can therefore not be described as flexible and relevant to address the needs of South African citizens. For years employers have been complaining that the products of our educational system are not always preparing learners for their roles in society. This outcry for skill-based education has been ignored and content-based education over-emphasised, because the demand for high pass rates has been gratified (Sigabi 1998:451).

The following comments of interviewees were drawn for question 1:

> *The term 'relevant' has different meanings for different people. I am of the opinion that biology education should contribute to: the personal and social development of the individual, the acquisition of biology knowledge by the learner and should enable the learner to use scientific methods and skills to solve a problem.*
>
> *South Africa needs a biology education that is issue-centred and skills-based.*
>
> *The current biology education can not be considered as totally relevant and flexible to address the needs of learners. Biology education should produce learners with skills and qualities which they will need in the workplace to improve their performance and to be able to adapt to changing needs and conditions of the community.*
>
> *Biology literacy, intellectual skills and knowledge, should be emphasised so that learners will be able to make reasonable decisions about community and individual issues.*
>
> *Relevant biology content, which includes the culture backgrounds of all learners should be taught towards the development of skills and the teaching of relevant biology content.*

From the above suggestions it can be concluded that biology education should be skills-oriented to enable learners to use scientific methods to acquire knowledge and solve problems in the community. Relevant biology content should be used where due consideration is given to the cultural differences of a multi-cultural South African population. Biology education should produce learners with skills and qualities needed to perform in their workplace and enable them to adapt to changing needs and conditions.

Question 2

What approach should be used to teach biology effectively (with the development of learners' process skills in mind).

The following suggestions were made by interviewees:

> *A possible approach is a process approach where a paradigm shift takes place from teaching to learning, where the permanent acquisition of educational outcomes, learning principles and skills are emphasised.*
>
> *The approach that should be used is an approach that will address the fundamental aim of biology education namely, to enable learners to develop the skills they need for life.*
>
> *Life-science themes which present problems associated with the needs of the community and the individual can successfully be used with a problematic approach when teaching biology.*
>
> *A process approach should be used to enable learners to develop skills they need for life-long learning.*

Of the 19 interviewees, 21%(4) of the suggestions were used as the other 79%(15) responses are similar. The interviewees indicated that a biology approach should be used to enable learners to develop skills that will enable them to learn for life. The possible approaches that can be used are a process approach and/or a 'problem' approach.

Question 3

If one considers a process approach (development of process skills) as important to teach biology effectively, why is this approach not implemented successfully in biology education?

All interviewees asserted that there are various factors that may hamper innovations in schools. As some interviewees pointed out the same negative factors, not all the comments are indicated below. According to the interviewees the following factors hamper the implementation of a process approach:

Exam-driven and content-loaded curricula:

> *The senior Certificate Examination is driving biology curricula.*
>
> *The whole educational system is examination orientated. For years the business sector has complained that the products of our educational system are not sufficiently prepared for the roles which they are to fulfil in the workplace. Thus rather than educating the learner to fulfil his role in society, the educational system has concentrated on "acceptable pass rates".*
>
> *The biology curricula are overloaded with facts that causes some of the biology teachers to concentrate merely on the transmission of content, rather than the development of skills.*

The exam-driven and content loaded curricula do not always allow enough time for the development of specific skills which learners need once they enter the workplace. Teachers are concentrating on 'pass results' rather than the development of skills that will enable learners to fulfil their role in society.

Curricula relevance:

> *Biology is sometimes taught by underqualified teachers who battle with curricula that are urban-biased, where examples are unfamiliar and inaccessible to the majority of learners (especially in HD schools).*
>
> *As a consequence of the school-going population of South-Africa being predominantly Black, I am of the opinion that the biology curricula in use (inspite of changes) are still not relevant to these learners. Irrelevant content may contribute to high failure rates*

of learners as content does not always reflect their life-experiences.

Sixty three percent (12) of the interviewees did not regard an irrelevant biology curriculum as sufficient reason for not implementing a process approach. Thirty seven percent (7) interviewees, however, stated that biology curricula are still irrelevant to the majority of disadvantaged learners. According to Jeevanantham (1998:229) the majority of disadvantaged learners (82%) in South Africa are being assessed on content that is irrelevant to their life-experiences. The consequences of this situation are various, but the most important is that many Black learners are not able to cope at school (high failure rate). Thus, by not coping in school they are excluded from economic and social life. Successful implementation of a process approach in biology education may largely be dependent on the relevance of the biology curriculum being taught.

Large classes:

Large classes, a lengthy biology curriculum and time have a major effect on the implementation of a process approach.

Large classes and the time factor can contribute to the unsuccessful implementation of a process approach. The reasons for this might be that large classes can create discipline and assessment problems in the biology classroom and cause learners not always to develop process skills. Teachers do not always have the time to discipline and assess large groups of learners and can thus not always determine whether learners have developed specific process skills.

The language barrier and socio-cultural differences:

Socio-cultural factors and values at work in the classroom may interfere with biology learning.

In the present multilingual context, the language and comprehension factor is often a overriding concern. Sometimes *central focus on English language and comprehension results in the neglect of the development of much needed science skills.*

Only 5 percent of the South African population is English first language speaking. The medium of instruction seems to be English for at least 82 percent of all learners. The problems of scientific language are therefore exacerbated by the problems of second language learning. The language one speaks not only consists of vocabulary but also includes unspoken expectations and assumptions. Teachers tend to forget that not all learners have the same backgrounds and underlying beliefs as themselves, particularly if they are fluent in the language used for teaching.

When one talks to a person from a different linguistic and cultural background one cannot assume that they will understand the inferences and assumption implicit in one's speech. Thus we can only expect learners to understand scientific concepts once they are functionally literate in this scientific language.

Of the interviewees, 38,58%(6) considered the language barrier as a problem when using a process appraoch. It is important that socio-cultural differences such as: learners' backgrounds, values, and underlying beliefs be considered when planning a biology lesson. Learners cannot always express themselves in a second language as they do not always understand the terminology, unspoken expectations and assumptions of the second language due to socio-cultural differences. Thus, mother-tongue education can contribute to the learners' understanding of scientific concepts and may enable learners to become functionally literate in the scientific language of biology.

Lack of infrastructure:

Some schools experience a lack of equipment, laboratories, copying facilities, shortage of textbooks, water and electricity supply, underqualified teachers that might contribute to the unsuccessful implementation of innovations.

Visits to schools in Soweto and Mamelodi revealed that not all schools are operating like it should. The following factors disrupted schools to a large extent:

Teacher absenteeism, staff meetings during school hours, teachers present but not teaching, timetables not completed in time for the beginning of the term, negative relationships between teachers, management and administrative staff, insufficient school funds, shortage of textbooks due to weak control when textbooks should be handed back at the end of year. Teachers' knowledge of biology tended to be limited to procedural knowledge. Classroom observations revealed that many of the teachers themselves had misconceptions about the biology they were teaching. Most schools have teacher pupil ratios of between 1:45 (in one school a Grade 12 biology class had 82 learners and at another school 60 learners in one class) and operate with 30-35 minute periods and the lack of copying facilities and paper. When one considers these factors it becomes clear why the biology failure rate in HD schools is high.

An interesting comment was made on the factor 'lack of infrastructure' (indicated by interviewees), in contradiction with the rest of the interviewees namely,:

Although the lack of biology laboratories are indicated as a possible reason for the unsuccessful implementation of change and the low pass rate of learners in HD schools, this reason appears not to influence learning as such. Laboratories hold status at a school but do not consistently boost a learner's achievement and may not always be relevant to teach basic biology concepts.

According to 89,47%(17) of the interviewees a lack of infrastructure (amongst others underqualified teachers, no water and electricity, no copying facilities, lack of textbooks and classrooms to teach) will contribute to the unsuccessful implementation of a process approach in biology education. The 'smooth-running' of the school, where factors such as teachers being present but not teaching; teachers' absenteeism; teachers conducting meetings and attending funerals during school hours and others, will also play a significant role in the implementation of a process approach.

Although the majority of interviewees replied that the lack of a laboratory will influence a process approach's success, 10,52%(2) of the interviewees responded that the lack of a laboratory will not influence learners' learning ability. According to them laboratories can be regarded as a status symbol at a school which may not always be able to contribute to learners' achievements and development of basic biology concepts. The lack of laboratories may therefore not influence the implementation of a process approach.

Teacher's knowledge of biology content:

> *During class visits in HD schools I experienced that teachers are not always competent to teach biology. Some of them lack the necessary biology knowledge and skills to teach biology effectively.*

Some teachers in HD schools might not be able to implement a process approach as they do not have the knowledge nor the skills to do so and may have to rely on unconventional methods.

The role of the parent:

> *The exam-results parents expect of their children can be considered as one of the main reasons why exam-driven curricula are still being followed in schools. Competition between schools has increased glossy brochures and computer screens (which is also advocated by parents), with less concentration on the successful Implementation of innovation in education.*

Parents can contribute to the successful implementation of a process approach in a school. Parents may be the reason why teachers stick to old traditional teaching methods, as parents expect their children to perform well in school. Parents should keep in mind that their children are learners and cannot be considered as customers switching from school to school as quality improves (Barker 1996:80). Parents may assist teachers by helping learners to develop process skills by practicing these skills at home.

Traditional teaching methods:

During practical teaching evaluation lessons, I experienced the following:

- *teachers are still using traditional teaching methods.*
- *learners were asked to solve tasks on the board that are written in the textbook as not all learners had textbooks.*
- *teachers' use of questioning was limited to simple factual recall. Challenging questions were not evident.*

In spite of a purposeful education change towards learner-centred teaching in South Africa, it seems as though some teachers are still using traditional teaching methods, such as the textbook and factual recall.

Teachers attending workshops and not implementing changes:

Although the aim of workshops is to change teachers and learners' conceptions, only minor changes occur. Some teachers still rely on traditional approaches to complete the curriculum even though they have attended several workshops.

Many teachers attend workshops that may enable them to implement innovation, but not all of them practice what they have learned in the classroom. As teachers still rely on traditional approaches, the value of workshops should be questioned.

From the comments above the following factors can be regarded as hampering the implementation of a process approach namely, exam-driven and content-loaded curricula, the language barrier, relevance of curricula, sosio-cultural differences, role of the parents, large classes, traditional teaching methods, lack of infrastructure, teachers' knowledge of biology content, teachers attending workshops and not implementing changes. All of these factors except for the factor 'the language barrier' were also indicated by sampled biology teachers as factors that influence the implementation of a process approach to a great extent. 'The language barrier' was emphasised by most interviewees (84,21%[16]) to have an effect on the implementation of a process approach while not all sampled biology teachers (of the empirical research) regarded it as an important factor (46,66%[13]) of HD schools' biology teachers and (36,73%[18] of HA schools' biology teachers).

Comments of certain interviewees concerning the importance of 'a supportive climate in your school to implement a process approach' are in agreement with HD schools' teachers (66,66%[20]) in contradiction with HA schools teachers' responses (38,77%[19]).

From these interviews it is also interesting that two of the interviewees indicated that a lack of laboratories in schools may not influence the implementation of a process approach, while the majority indicated it may.

Question 4

How can the factors that might hamper the effective implementation of a process approach be combated?

Relevant curriculum content:

> *The renewal of biology curricula should include more of the cultural experiences of Black learners, thereby, enhancing the possibilities of Black learner success in the biology class as far as the implementation of innovations are concerned.*

The high failure rate of Black learners can possibly be addressed by including their cultural experiences in biology curricula. Jeevanantham (1998:217) states content should be relevant to learners of all races, thereby enhancing the possibilities of Black learners' success in biology education.

A flexible timetable:

Learners with diverse learning styles and learning tempos should be given extra time to complete their tasks. Extra-curricular or extra-mural activities and classes can be provided for learners learning at a slower rate. Time should also be allocated for teachers to attend workshops and lesson preparation.

The school-day should provide time for teachers to prepare lesson activities and enable the slower learner to complete his/her work by means of extra activities after school. By allocating flexi time to the school timetable, teachers may have time to organise and plan activities that will contribute to the implementation of a process approach.

The attitude of the biology teacher:

A positive attitude of the biology teacher will influence the implementation of innovations. The teacher is in the position to promote a positive climate in the classroom.

The biology teacher's attitude towards changes will influence not only the learner's attitude towards changes but also the success of these changes. If teachers are not able to manage or control large classes especially Grade 12 classes, they can work with universities, technikons and NGOs to assist them with mentors that can support teachers to implement changes effectively.

School principals should assist innovations:

A positive climate for changes can be created by attending symposiums, workshops and conferences. These workshops and others will only be of value to the biology teacher if the school functions smoothly and the principal assists teachers to implement innovations. It is therefore, important that school principals will be motivated to assist change.

A positive atmosphere at school should be created by the principal to assist teachers to implement a process approach. The principal should change his/her management styles and procedures to accommodate changes.

Pre-service and in-service training of teachers:

Pre-service and in-service training of teachers should emphasise the necessity that teachers understand learners' cultural backgrounds and interests, ways learners' interests can conflict or harmonise with western science, how learner-centred curricula can be designed and the role of biology teachers.

In-service support should be provided to biology teachers, not only by providing theoretical documents on innovations but also by providing teachers with concrete examples of what this means for teaching biology.

The problem with large classes can be addressed by specifically training student-teachers and teachers to handle such large classes.

Teachers should be trained to use different strategies and methods in order to teach large classes and should consider the different cultural backgrounds of learners. Teachers can be guided through practical examples to change their approaches.

Large classes:

Teachers need to be creative to handle large classes. For example a leader can be selected in each group to support and guide the slower learner in the group. Learners in each group can assess themselves and one another while the teacher facilitates. The teacher's creativeness will play a major role when he/she teachers biology.

Teachers should be supported to handle large classes and be provided with practical examples of how learners' process skills can be developed in biology education. According to the researcher this can be done by issuing teachers with planned lessons (which they can alter and elaborate on) for a specific grade as examples rather than issuing them only with theoretical information which they do not always know how to use.

Distance education:

> *The problem of large classes, lack of laboratory equipment, the time and financial constraint might be solved through distance education, where one teacher can guide a large group of learners. Distance education can be highly cost effective when large number of learners follow the same courses. In rural areas individualised study can be provided by including clear learning objectives, learner activities by using self-instructional kits, self-assessment materials and opportunities for feedback during group discussion sessions or on demand.*

Walberg (1991:53) asserts that distance education should be considered when a large number of learners have to be taught the same biology curriculum. Distance education is not only cost-effective but can also fulfil in the need for individualised study. Books, newspaper supplements, posters, self-instructional kits, films, computer-assisted learning and many other media may work consistently better than oral teaching.

Alternatives for expensive laboratories:

> *One fully equipped laboratory at a school is sufficient for all biology learners. A classroom can be equipped with home made apparatus. The timetable should accommodate all learners to visit the laboratory at least once a week.*
>
> *Videos and computer simulations can be used to demonstrate lengthy or maybe dangerous experiments.*

A classroom can be used as a laboratory and improvised apparatus can be made where no equipment is available. Alternatively, the timetable should be flexible and make it possible for all biology learners to work in the laboratory at least once a week. If experiments are lengthy, dangerous or the teacher does not know how to conduct it, computer simulations and videos can be used to demonstrate the experiment.

Use cost-effective and easy accessible equipment:

To address the lack of equipment and laboratories teachers should be encouraged to be creative in order to find alternative ways when doing practical work. For example, two-liter coke bottles can be used as measuring apparatus. If it is possible biology teachers can work with nearby employers or farmers to demonstrate biology principles in traditional and new technologies. Field trips can be meaningful when learners are given practical experience and insights in local problems and equipment used.

Cost-effective simple equipment can be used in both HD and HA schools as these materials are simple in design and may enhance learners' observations and understanding of the experiment.

Using cost-effective, everyday, easily accessible materials and equipment may prove beneficial especially in schools that experience a shortage of apparatus to conduct experiments. Low-cost equipment and materials which are simple in design allow learners to understand the underlying principles more easily and make teachers less concerned about possible damage when learners use it. The provision of spare parts for, and the repair of, locally produced equipment are not difficult problems to solve if the equipment is built at the school using locally available or scrap materials. Layton (1988:224) elaborates that the use of low-cost simple equipment is not only a concern for developing countries. Many industrialised nations have introduced low-cost equipment for pedagogical reasons, recognising its use can enhance learners' understanding.

Fieldtrips to nearby industries may enrich biology curricula by allowing learners to experience local problems practically and to become familiar with technology that can be used to solve problems.

The role of the parent:

The ideal parent, one who is willing and able to participate in his/her child's education is rare. But schools can improve parent and grandparent involvement in the development of their children's process skills by inviting them to tell learners about their experiences in the past, assessing parents' needs, get to know them individually, offer a broad range of activities to encourage support, personalise home-school communications. Making parents feel comfortable is important to get them involved in their child's learning.

Skilled parents should train illiterate parents on how to develop their childrens' skills at home. Teachers can also assist parents by helping to monitor childrens' development of skills.

The involvement of parents with the development of their children's process skills can lighten the biology teacher's load. For example, grandparents of different cultural backgrounds can be invited to the class to tell learners about their experiences in the past. Skilled parents can also train other parents in the community, who are not able to assist their children in the development of process skills.

Question 5

Which methods should be used to develop learners' process skills?

The following answers of 31,58%(6) interviewees were selected to indicate methods that should be used to develop learners' process skills:

In general:

The lack of a teaching methodology for biology may influence successful learning and the development of a positive attitude. It is important that methods to develop process skills will be thoroughly considered before used.

Teachers should be trained to use various methods and strategies which can contribute to the successful implementation of innovations.

Inquiry/problem solving activities:

Practical work should be emphasised where learners are posed with a problem that will interest them in finding solutions for the problem.

Although practical work in the laboratory is advocated by many education specialists, many learners perform experiments without understanding the purpose of the experiment. It may also sometimes occur that the biology teacher has little knowledge or control of what happens in the different lab groups leaving the learners with a feeling of helplessness and uninvolvedness. I would suggest that learners of especially HD schools will benefit more from watching demonstrations, computer-simulations and film loops or strips than actually doing the experiment in the laboratory.

Practical work can contribute to the development of process skills if learners are posed with a problem and have to solve the problem by using different skills. As practical work in laboratories can be very costly, it is important that alternative methods should be used to conduct experiments. This can be done by letting learners watch...

- an experiment demonstrated by the teacher or a learner from the class;
- computer simulations of dangerous and long experiments and
- films of experiments.

Inquiry activities are important to develop process skills. It is vital that teachers are carefully trained in using inquiry activities and are provided with continuous guidance and support on how to use these methods successfully.

Use methods that will enable learners to develop thinking skills. Teaching for thinking should be done deliberately through inquiry activities by the teacher.

Develop problem-solving skills through inquiry activities, by using process skills.

When learners are actively involved in biology activities, observations or unexpected discoveries might stimulate their curiosity and interest to learn more.

All learners should receive the opportunity to develop process skills by means of inquiry methods. However, inquiry methods can waste time unless skillful teachers carefully prepare and supervise the activities.

Inquiry methods not only allow learners the flexibility to examine relevant problems, but also enable learners to use different process skills to solve these problems.

According to the majority of interviewees (89,47%[17]) inquiry methods can be considered as one of the most important methods to develop learners' process skills. Inquiry methods enable learners to use different skills to solve problems. It is important that teachers are carefully trained to use inquiry methods when teaching biology as this method can be very time-consuming if not planned correctly. According to 36,84%(7) interviewees, teachers should also be provided with continuous guidance and support by specialists on inquiry methods to ensure the successful use of these methods when implementing a process approach.

Group work and co-operative learning:

Learners who are taught individually rather than co-operatively can fail to develop skills that are needed to work with other learners. In the co-operative conditions of the workplace, knowing how to learn and work together is increasingly important. If learners are going to learn and work in conjunction with others, activities should be created where they can develop these skills.

> *Instructional situations should be learner-centred by using the co-operative method where learners actively inquire about phenomena in their 'raw state'.*
>
> *Group work should be encouraged where learners can discuss their ideas with other learners using commonly accepted concepts and meanings. By making use of group work the learners can more freely discuss their ideas with their fellow learners while the teacher serves as facilitator.*

Co-operative working skills of learners are necessary for learners to cope in a collaborative workplace (Brown *et al.*1989:34). If learners are going to learn and work in conjunction with others, they must be given the opportunity to develop those skills.

When using the group work method, learner-centred teaching is advocated where the teacher serves only as facilitator and learners have more freedom to discuss their conceptions with fellow learners. To use group work effectively as a method, the biology teacher should prepare carefully and supervise all activities.

Question 6

Are teachers adequately trained to implement a process approach?

Comments that were drawn from interviewees were as follows:

> *In-service and pre-service teacher training demands attention to overcome the shortage of qualified biology teachers.*
>
> *The reasons why Curriculum 2005 had to be reviewed can be related to poor co-ordination and insufficient teacher training.*

Pre-service training:

> *If pre-service student teachers are actively engaged in activities where skills are developed, they will understand and remember these activities and will in turn be able to implement such activities in the classroom.*

Universities, colleges and NGOs should all work together to train biology teachers effectively. Outcomes stipulated by the NQF, should be used to train and evaluate student biology teachers. For every outcome reached, a student-teacher should be credited, whether at a university, college or NGO. All credits should contribute to a certain outcome.

Training, practising and modifying the recommended teaching strategies to suit change must be emphasised by training institutions.

In-service training:

Training should ensure that teachers are familiar with content knowledge which goes beyond the content of the biology curriculum.

Teachers should be visited by subject facilitators or researchers on a regular base to assist teachers with the implementation of a process approach. This can promote good working relationships between teachers and subject experts.

To combat the financial constraint of education, four to five schools can be grouped together, with a mentor who assists teachers with ideas and solutions to overcome possible problems.

Train teachers according to a hands-on approach that will encourage them to be creative and innovative when a lack of apparatus is experienced.

To facilitate changes such as the implementation of Curriculum 2005 in South African schools it is important that the Education Department will approach competent trainers at universities and colleges to train teachers. That will ensure that teachers are properly trained in the new system. Some teachers are complaining that they are trained by incompetent Curriculum 2005 trainers that are financially draining the Education Department, as many of the teachers who attended Curriculum 2005 courses still do not know how to implement this.

Education departments and training institutions should work together when implementing changes.

If teachers are trained to create exciting learning opportunities where learners can develop process skills, teachers might also reflect a positive attitude towards change.

Teachers should be trained and motivated to change their teaching strategies and to modify these strategies to suit their needs.

Pre- and in-service training of teachers will play an important role in the success of a process approach. In-service training of teachers should ensure that the teachers are trained by competent trainers and that these trainers should also assist teachers in the practical implementation of a process approach in the classroom. Alternative assessment strategies should also be emphasised.

Teachers should be trained to:

- create exciting learning opportunities to develop learners' process skills;
- be creative and innovative in order to combat the lack of practical equipment and
- be familiar with the content that he/she is teaching in the biology classroom.

The comments of the interviewees contributed to the recommendations that will be discussed in Chapter Nine.

8.3 SUMMARY

Interviews were conducted with 19 subject- and education specialists to obtain information that can contribute to the successful implementation of a process approach. Most of the interviewees were of the opinion that biology curricula do not address the needs of the community. The biology curricula do not always consider the cultural background of the various population groups. Biology education should be skill-orientated to enable all learners to learn for life. A process and a problem-solving approach should be used.

The following factors were indicated by interviewees to influence the success of a process approach namely, exam-driven and content-loaded curricula, the language barrier, relevance of curricula, sosio-cultural differences, role of the parents, large classes, traditional teaching methods, lack of infrastructure, teachers' knowledge of biology content, and teachers attend workshops but fail to implement changes. Two of the interviewees did not consider the lack of laboratories and equipment as negative factors as learners are not dependent on expensive apparatus to make observations and form conclusions.

Negative factors influencing a process approach's implementation can possibly be addressed by including more cultural experiences of Black learners in biology curricula. The principal should run the school smoothly by assisting teachers to implement innovations; consideration should be given to distance education and the usage of cost-effective and easily accessible equipment; and parents should be involved with the development of their children's skills.

The inquiry method was indicated by the majority of interviewees to be the best possible method to develop learners' process skills. To ensure that teachers are able to implement innovations and be able to use the inquiry method, teachers will have to be trained accordingly (pre- and in-service training).

8.4 CONCLUSIONS

The empirical research and interviews conducted contributed to the opinions throughout the literature study that various factors hamper the effective implementation of a process approach. It is important that negative factors such as 'large classes'; 'a lengthy syllabus'; 'lack of equipment' and 'lack of resource material' (in HD and HA schools) which received high percentages in the survey and was indicated by interviewees, will duly be considered by curriculum developers. These factors can exert a powerful influence on the success of any changes in biology education.

The academic qualifications, professional status and teaching experience of the biology teacher may contribute to the successful implementation of a process approach. From the research study it is evident that the majority of teachers are qualified and experienced to teach biology, but not all know what a process approach is. The reason most probably is as Fraser (2000 *pers. comm.*) comments, that not all teachers receive adequate in-service training to stay abreast with innovations. In-service training plays an important role in the successful implementation of a process approach.

CHAPTER NINE

PRINCIPAL FINDINGS, RECOMMENDATIONS AND IMPLICATIONS

9.1 INTRODUCTION

In this study the possible problems that might influence the successful implementation of a process approach in biology as a subject were identified. Problems were identified within the biology curriculum, the infrastructure for biology education and biology teaching methods. Lengthy content-laden curricula may emphasise the memorising of facts by means of expository teaching methods, leaving little opportunity to teach the application of information and the skills to solve problems in real life situations.

Several researchers (vide 1.1) in the South African education system indicate the advantages of developing process skills. The successful implementation of a process approach should be considered to be one of the important aims of biology education. Notwithstanding the important contribution of a process approach to biology education, various factors hamper the successful development of process skills in the biology classroom (vide Chapter Two and Table 7.8).

The main purpose of this research was, therefore, to identify factors that prevent the implementation of a process approach in the biology classroom. The most felicitous way to identify these factors was to perform a literature study and to undertake empirical research with a sample of teachers and to conduct interviews with subject- and education specialists.

9.2 PRINCIPAL FINDINGS FROM THE LITERATURE STUDY

The literature study acquainted the researcher with the main findings of recognised authorities and of previous research in this field.

9.2.1 Factors which cause ineffective biology education

The belief amongst educators surveyed, indicated the following main factors that possibly cause ineffective biology education:

- The biology curriculum: the senior secondary biology curriculum may be described as discipline-based, content loaded and largely irrelevant to the majority of learners who will not further their studies in a biology field as some teachers have not changed their old teaching methods.

- Infrastructure for biology education: not all schools are equipped with the infrastructure needed to successfully implement changes. Biology teachers should be innovative and creative to improvise practical work.

- Biology teaching methods: the present teaching and learning of biology is believed to be largely expository in nature and does not always provide learners with the necessary opportunities to develop process skills by means of inquiry activities (vide 2.2.3).

A solution to combat these problems needs to be suggested to fulfil the goal of a democratic South Africa namely:'...to educate every citizen in order to learn for life' (Department of Education 1994:23; Kahn 2000:8 and NQF 1996:5). From the researcher's personal opinion it is important that an education system should be used which is skills orientated, and which enables learners to apply the skills they have learned where applicable in all other subject areas to solve relevant life situation problems.

9.2.2 A process approach in the teaching and learning of biology

Chapter Three identified a process approach as a possible approach which will contribute to effective biology education. Biology teaching should provide learners with opportunities to develop process skills by means of a process approach, which will enable them to acquire and apply knowledge in real life situations (vide 3.4.3).

Process skills can be divided into basic skills and integrated skills. Basic process skills can be described as those primary (simpler) skills that a learner develops. These skills are used from pre-primary school up to Grade 5, namely observing; inferring; classifying; measuring; predicting and communicating. These basic process skills can be considered as prerequisites for the integrated (higher cognitive) biology process skills. Integrated skills are dependent on the learner's ability to think on a high level and to consider more than one idea at the same time. The term 'integrated' implies that various of the basic process skills can be combined to solve problems (Martin *et. al* 1997:15 and Mossom 1989:74). Integrated process skills are skills needed to execute scientific experiments. These skills which consist of defining operationally; interpreting data; identifying and controlling variables; formulating hypotheses and experimenting, are developed in the higher grades, namely six to twelve (vide 3.4.3.2).

9.2.3 Implementing a process approach

In Chapter Four it was indicated that process skills cannot develop in a vacuum, they need to be woven into appropriate content areas, and used in everyday life situations. A process approach which is learner-centred not only contributes to the development of learners, but has several advantages for biology learners, teachers and the new South African education system (vide 4.2, 4.3 and 4.4). The importance of a process approach is stressed by indicating the resemblance between this approach and *Curriculum 2005*.

Notwithstanding the advantages of a process approach, it has several disadvantages. The objections levelled against it are: it is time-consuming; lack of material and sources of information hamper the use of this approach; teachers are not competent enough to implement the approach and the work load of the biology teacher increases when it is implemented (vide 4.6). If a process approach is adopted, teachers' attitudes; their views; their knowledge of the approach and the learners involved need to be considered (vide 4.7). Different methods can be used by the biology teacher to change to a process approach.

9.2.4 Methods that can contribute to the implementation of a process approach

Problem-solving and the use of inquiry methods to develop process skills, have been stressed in Chapter Five. It is advocated that the use of explicit instruction procedures will engender the development of process skills (vide 5.2).

Since there is no one single method that can be adequate by itself, it is important that biology teachers should select various methods which might best develop process skills. Studies conducted earlier by Mossom (1989) and Mhlongo (1997) on the development of process skills, indicate that inquiry methods have proven to be successful methods to develop process skills. Inquiry methods such as the questioning method, practical work (which includes laboratory and field work), the project method and the small group method (co-operative learning method) were discussed as well as some of their advantages and limitations.

The literature study, therefore, suggests that the solution to impediments resides in the changing of existing methods; less emphasis on content and more on skill development of learners; provision of infrastructure and implementing outcomes-based learning to enable learners to solve problems in the community. A process approach should be implemented which will enable learners to develop process skills, and this in turn will enable them to apply the knowledge they have gained, to real life situations.

9.3 PRINCIPAL FINDINGS FROM THE EMPIRICAL RESEARCH

The empirical research investigated whether or not the findings in the literature study can be confirmed. Chapter Six indicates the design of the empirical research that was used to investigate the reasons why a process approach is not successfully implemented in secondary school biology education.

9.3.1 Empirical research strategies

The empirical research strategies, as followed in this study, are outlined in Chapter Six. Questionnaires were completed by a small sample of biology teachers in the Gauteng Province and interviews were conducted with several subject- and education specialists, in order to determine why a process approach is not successfully implemented in biology education. Analyses of the teachers' questionnaires revealed that HD and HA schools' teachers have different perceptions concerning the factors that hamper the implementation of a process approach. Therefore, it was imperative to compare HD and HA schools' responses to one another.

9.3.1.1 Major findings of questionnaires

(a) Qualifications and teaching experience of biology teachers

Sampled biology teachers' qualifications and teaching experience may determine whether or not they are able to implement a process approach successfully. Responses of questionnaires indicate that most biology teachers of both HD and HA schools have at least a three or four year diploma in the teaching of biology (76,7%[23] and 46,93%[23]). The majority of teachers indicated a teaching experience of more than six years (76,67%[23] of HD schools and 85,7%[42] of HA schools). When one considers the qualifications and the teaching experience of biology teachers, it appears as though most of them should be able to implement a process approach.

(b) Biology teachers' knowledge of a process approach

A process approach can be described as a number of processes which learners use during biology activities to develop intellectual skills in order to acquire information and understand concepts involved. This process includes basic- and integrated process skills (Mossom 1989:39 and vide Chapter Three). When using a process approach, process skills form the bases of biology education and content is introduced as needed. The assumption is that if learners develop process skills, they may have a better understanding of this content.

The survey conducted in this research, finds that only 13,33%(4) of the sampled HD sampled schools' teachers and 4,18%(2) of HA schools' teachers do not know what a process approach is. If teachers are not familiar with a process approach, they may not be able to implement it. The researcher ascertained whether teachers are familiar with the approach by telephoning them individually to ensure that any doubts were addressed.

(c) Characteristics associated with a process approach

Teachers were requested to indicate the extent to which they use the characteristics associated with a process approach. Thirteen such characteristics were listed in the questionnaire (vide Table 7.3). Of the sampled teachers 55,7%(44) indicated they use the characteristic 'learners organise data and draw conclusions from it' 'often' and 25,3%(20), 'always'. This high percentage is understandable, since many teachers have been introduced to OBE principles which are learner-centred, where learners should form their own conclusions based on data. Another possible reason might be that they find this feature as the simplest to implement in their teaching strategies (vide 7.2.3.2).

Of the respondents only 17,7%(14) indicate that they allow learners to design their own experiments 'often'. This finding may have implications for the implementation of a process approach, since the skill to plan and design experiments has been identified as an important component of inquiry activities (vide Table 7.5).

Other characteristics that biology teachers do not frequently use, are: 'learners choose an issue or problem to investigate' (40,5%[32] responded 'often' and 5,1%[4] 'always') and 'learners form their own questions about the world around them' (40,5%[32] responded 'often' and 8,9%[7] 'always'). As mentioned before, HD and HA schools teachers' teaching methods differ due to certain factors. Therefore, HD and HA schools teachers' responses are compared to one another. 'Learners do experiments' was ranked at a lower level by teachers from HD schools. Of the sampled HD schools' teachers, 23,33%(7) responded 'often' when compared to teachers of HA schools where 75,5%(37) responded 'often'. The reasons for this may be related to the possibility that teachers who lack equipment and sufficient training in order to be creative, experience impediments when doing experiments (De Beer 1995:36 and Slabbert 1997:18). Analyses of the questionnaires indicate that HA school teachers use the characteristics associated with a process approach more often than those from HD schools.

(d) The importance of inquiry activities to develop process skills

Biology teachers were requested to indicate the frequency with which they do inquiry activities (field work, certain practical work and project work) in their teaching. Of all the responses 53,2%(42) indicate that they allow their learners to do inquiry activities 'frequently' (vide 7.2.4). However, when HD and HA schools' teachers responses are compared, it becomes clear that only 26,6%(8) of HD schools' teachers are using inquiry activities 'frequently'(vide Figure 7.6). It can be concluded that not all HD school teachers frequently use inquiry activities and may not be able to develop learners' process skills. The reason for this could be related to factors that prevent the successful implementation of a process approach.

(e) Factors which may prevent the successful implementation of a process approach according to the sampled teachers

Biology teachers were requested to indicate the extent to which various factors affected the implementation of a process approach. Twenty seven such factors were listed in the questionnaire (vide Table 7.7).

Although teachers were requested to add to the list, no additional factors were added.

The analyses of the sampled teachers' questionnaires revealed that all twenty seven factors affect the implementation of a process approach to some extent. Percentages ranged from 93,33%(28) (HD schools' teachers) for 'large classes' to 20,40%(10) (HA schools' teachers) for 'insufficient infrastructure' (vide Table 7.9).

Both HD and HA school teachers claimed that large classes can be a barrier when developing and assessing learners' process skills. Research conducted by De Beer in 1993, indicates that in some HD schools the learner-teacher ratio is 60:1 per class. These numbers are still increasing every year because of the limited budget for education. Teachers indicate that they avoid doing inquiry activities such as field work, laboratory work, and practical work. Thirty three percent (10) of HD schools' teachers indicated 'once a year' and 10%(3) 'not at all', while of the HA schools' teachers, 6,1%(3) indicated 'once a year', and 0%(0) 'not at all' (vide Figure 7.6). The reason why teachers are avoiding inquiry activities could most probably be related to inadequate teacher training; lack of equipment 'to a great extent' (76,6%[23] of HD schools) and 'to a great extent' inadequate resource material (73,33%[22] of HD schools)(vide Table 7.9). Thus the neglect of inquiry activities may be aggravated by the lack of properly equipped laboratories and suitably qualified teachers.

Factors such as, 'a lengthy syllabus' and 'teacher-centred teaching' were also indicated by both HD and HA schools' teachers as having an effect on the implementation of a process approach. Teachers pointed out that they are battling to work through a lengthy syllabus with the final examination in mind. 'A lengthy syllabus' leads to teacher-centred teaching in an attempt to finish the syllabus on time.

(f) The value of the development of process skills

The development of a science literate nation is crucial for South Africa's survival (Kahn 2000:8). Learners should develop the necessary skills that will enable them to make critical decisions concerning nature. Therefore, it is important that biology programmes should be designed to serve the needs of the large group of matriculants who will not further their studies at tertiary level in a science related field (Pepper 1995:1-10 and Spargo 1995b:30-34).

In contrast to the above, analyses of the biology teachers' questionnaires indicate that the majority of teachers (60%[18] of HD schools and 51%[25] of HA schools) are of the opinion that the development of process skills is only necessary for those learners who will further their studies in a biology related field at tertiary institutions (vide 7.2.6). Teachers are under the impression that the target group for which the development of process skills is the most valuable will be for those learners who will further their studies in a biology related field at tertiary institutions, since knowledge and skills are only essential for success at tertiary institutions.

9.3.1.2 Major findings of interviews

Structured interviews were held with biology subject- and education specialists to obtain information that can contribute to the successful implementation of a process approach.

(a) The relevance and flexibility of biology curricula to address the needs of South African citizens

Biology curricula cannot always be regarded as totally flexible and relevant to address the needs of learners. The diverse cultural backgrounds of the population in South Africa are not always considered when constructing curricula and consequently not all citizens are able to contribute to the economic growth of this country. Biology education should produce citizens with skills and qualities that are needed in the job market and that will enable them to improve their performance. For years employers have been complaining that the products of our educational system are not always preparing learners adequately for their roles in the society. Not all learners are sufficiently equipped to cope with the demands of the skill-based job market. This outcry for skill-based education has most probably been ignored because the demand for high pass rates has been gratified.

Biology literacy, knowledge and intellectual skills should be emphasised in biology education to enable learners to make critical decisions concerning community and individual issues. Learners should be able to use scientific methods when solving problems and develop skills and qualities needed to perform in their workplace.

(b) The approach that can be used to teach biology effectively

The interviewees indicated that a biology approach should be used that will enable them to learn for life. The possible approaches that can be used is a process approach and/or the problem-solving approach where learners develop skills that will enable them to acquire information and use it to solve problems in the community.

(c) Factors that may influence the implementation of a process approach

There are various impediments that may influence the implementation of a process approach.

The biology curricula are mostly overloaded with facts and are exam-orientated which cause some biology teachers to concentrate on the transmission of content, rather than the development of learners' skills. This has serious implications for the business sector in South Africa, as learners are not properly prepared to fulfil their role in the workplace and in society.

Although changes have been made to biology curricula, some of the curricula in use are still not relevant to many Black learners. Content is sometimes unfamiliar (urban-biased), inaccessible and does not always reflect Black learners' life experiences.

Irrelevant content can contribute to the high failure rate of Black learners. Large classes, a lengthy syllabus and the time factor should be considered when implementing a process approach. Teachers may decide not to use a process approach in large classes as discipline and assessment problems might occur.

When teaching biology, different linguistic and cultural backgrounds of learners could influence the understanding of scientific concepts taught. Learners may have different beliefs and values that can interfere with biology learning. Mother tongue education would be ideal if the required terminology is developed.

Although the lack of a laboratory is indicated by sampled biology teachers as a possible problem that may influence the development of learner's process skills, 10,52%(2) of the interviewees are of the opinion that it should not be considered a problem. The lack of a laboratory should not influence the development of learners' process skills. A laboratory is a convenience but not a necessity to implement innovations.

Parents may sometimes inhibit teachers to implement changes. The reason might be that parents expect good results from their children, thus causing teachers to resort to traditional teaching methods to ensure that learners perform well in examinations. Assessment procedures need to be reviewed.

Regardless of all the changes that have taken place in South African education, it seems as though some teachers are still relying on traditional methods, where facts have to be recalled and problems solved from the textbook. It should be interesting to see, a couple of years from now, whether the new OBE textbooks have changed this. OBE textbooks for the Senior Phase come with comprehensive teacher's guides, with helpful suggestions on teaching methods.

Some of the teachers who attend workshops still do not implement the innovations they have learned. Traditional approaches are still used to complete the curriculum in time. Thus the contribution of workshops should be questioned, unless principals assist teachers to implement innovations. Principals should encourage and support changes and ensure that schools run smoothly.

(d) Solutions to possible negative factors that can hamper the effective implementation of a process approach

Black learner success in biology can possibly be enhanced by including their cultural experiences in curricula. Biology content needs to be relevant to learners of all races.

Pre-service and in-service training of teachers should emphasise the handling of large classes and understanding of learners' diverse backgrounds and interests. When implementing changes, teachers should not only be provided with the theoretical documents on these changes, but also with practical examples which they can use when teaching.

Distance education can be considered to solve the problem with large classes; lack of laboratory equipment; the time factor and financial constraints. One teacher can guide a large group of learners cost-effectively. Through distance education learners (especially in rural areas) can engage in individualised study if supported by clear outcomes, learner assignments, self-assessment activities and discussion sessions. From these activities it can be determined whether learners are progressing and if they encounter any difficulties with the subject as such. Self-instructional kits, computer-programmes, films, posters, books, newspapers and other learning material may work better than traditional oral teaching methods.

Simply designed, cost-effective equipment can be used in both HD and HA schools. Teachers should be encouraged to be creative and to find alternative ways to conduct experiments. They should make use of nearby facilities and attend to local problems when practical work is executed.

Communication between parents, grandparents and the school should be encouraged. Parents and grandparents that are willing to participate in the development of their children's process skills, should be encouraged to become involved. Skilled parents can offer guidance to other parents in the community who are not able to assist their children in the development of process skills.

(e) Methods that can be used to develop learners' process skills

Inquiry methods can be considered important to develop learners' process skills. Teachers should be trained, continuously guided and assisted to use inquiry methods effectively and efficiently. Inquiry methods enable learners to use different process skills to think critically and to solve relevant problems.

Practical work should be emphasised so that learners are able to find solutions to problems. Practical work need not be conducted in expensive laboratories. Learners may benefit more by watching demonstrations of experiments, computer simulations, film loops or strips of experiments.

Learners should be encouraged to work co-operatively with fellow learners. As future adults, learners have to learn to work with others in the co-operative conditions of the workplace. Therefore, activities should be created where learners can work together in groups. Working together in groups also encourages learners to share their ideas with one another by using accepted terminology and concepts while teachers serve as facilitators. This in turn, develops communication skills.

(f) Training of biology teachers to implement a process approach

The possible shortage of qualified teachers can be addressed by emphasising in-service and pre-service training of teachers. Teachers can attend a forty or eighty hour in-service training course during school holidays. By attending such a course teachers will be credited either for their personal progress or national learning hour or for an academic qualification. Universities, NGOs and colleges should all work together in training student-teachers to be actively involved in activities on how learners' process skills can be developed. Being actively involved will enable student-teachers to remember these activities and enable them to implement such activities when teaching biology.

Teachers should be trained to create exciting learning opportunities, be creative and innovative when conducting experiments and be familiar with the content he/she is teaching.

9.4 EMERGING FROM THIS STUDY

Views and recommendations presented in this study hold for the researcher's experience in general, the empirical research and interviews conducted with subject- and education specialists. It is with this limitation in mind that the researcher reflects on factors which might hamper the successful implementation of a process approach.

The possible teaching methodology teachers use when teaching biology and negative factors that might influence the development of process skills, are the central issues which emerged from the study.

9.5 RECOMMENDATIONS AND IMPLICATIONS

South Africa is facing a complex and uncertain future - a future characterised by increasing unemployment, poverty and disease (Spargo 1995b:30). Solutions have to be found to combat these problems. It is believed that skills-based biology education can be considered as a possible foundation for both long-term economic growth and an improved distribution of economic opportunities and income (Kahn 2000:8 and Wright & Govindarajan 1992:269-271). In order for South Africa to develop an economy which is competitive and successful, it needs an education system that will provide a skilled workforce (Centre for Education Policy Development 1995:4-5). According to Curriculum Frameworks for Science, Technology and Mathematics (1995:3), learners need to develop skills that will equip them for life and enable them to think critically when making decisions to solve problems. Therefore, it is important to address the impediments that might cause ineffective biology education. Spargo (1995b:30) is of the opinion that the biology curriculum should be designed to serve the biological needs of the very large group of matriculants who have no intention of studying further in a biology-related field at tertiary level. Vermaak (1996:*pers. comm.*) is of the opinion that South Africans need biology education that is issue-centred and skills-based.

The attempt of the Department of Education to apply *Curriculum 2005* to all South African schools proved that a new curriculum document as such does not guarantee successful implementation, even if it is based on convincing insights. Slabbert (1997:11) points out that the replacement of an old textbook or changing the prevailing rationale of a syllabus, does not necessary ensure real instructional change. Slabbert (2000:*pers. comm.*) is of the opinion that the approach that is used should address the fundamental aim of biology education namely, to enable learners to develop the skills they need to learn for life. Furthermore, the lack of a teaching methodology for biology which may contribute to successful learning and the development of a positive attitude, will also play a significant role.

9.5.1 Methods and strategies to teach biology through a process approach

As class sizes and infrastructure differ in HA and HD schools, it is important that a variety of teaching and learning methods and strategies associated with the characteristics of a process approach should be used to facilitate the development of learners' skills.

9.5.1.1 Motivation

It is widely believed amongst subject- and education specialists that the biology curriculum, large classes, the time factor and the Senior Certificate Examination in biology, encourages the biology teacher to use formal teaching methods with the aid of a textbook, where the learners only observe passively. For years the business sector has complained that learners are not sufficiently prepared for their roles in the workplace. The educational system has mostly concentrated on high pass rates of learners rather than to educate them to fulfil their roles in the community.

It is important to use methods that will enable learners to develop skills and gain relevant information which they can use to solve real life problems. Therefore, thorough consideration should be given to methods that develop learners' process skills.

Learners should gain experience in seeking knowledge in the same way as biologists do. Biology as a subject should not be taught as a rhetoric of conclusions, but as a dynamic process of asking questions and seeking answers. Learners should investigate real problems, they should become skilled in using the processes that a biologist uses such as designing experiments (controlling variables); formulating hypotheses; collecting; analysing and interpreting data.

Inquiry activities where learners are posed with relevant problems that are of interest to them should be emphasised. Inquiry methods enable learners to learn within an atmosphere where they can explore freely and exchange their ideas with fellow learners.

When learners leave school they should be equipped to understand the bio- social issues of today and tomorrow, and be able to find solutions to any problem that might arise.

9.5.1.2 Implications

To facilitate the development of learners' process skills that will enable them to learn for life, a variety of teaching and learning methods associated with the characteristics of a process approach should be utilised.

This has the following implications:

(a) Notwithstanding, changes in the education system the past few years, Figure 7.6 reflects that some of the teachers are still using traditional instructional methods. There should be a departure from traditional instructional methods such as the textbook-based and teacher-centred lecturing methods, towards inquiry-based teaching methods. Learners should be provided with opportunities to develop the necessary skills and attitude to acquire information.

(b) If we accept that the development of process skills are important for biology education, then the examination of useful methods to enhance the development of process skills attains considerable significance.

(c) It is a widely held belief amongst prominent South African biology educators that the development of process skills in biology education may best be achieved by using inquiry methods. This not only allows learners the flexibility to examine problems of particular relevance, but also incorporates a large scale use of process skills. When actively involved in an investigation, an unexpected result or observation can easily captivate learners' interest in a new learning area. Subsequently new variables can be defined and an appropriate experimental design can be created to solve problems.

(d) Although sampled biology teachers commented negatively to 'group work' in Chapter Seven, education- and subject specialists are of the opinion that learners should be encouraged to discuss their ideas with other learners using commonly accepted concepts and meanings as these skills will help them once they are exposed to the collaborative workplace. Thus by allowing learners to be involved in their own investigations, they tend to rely less on the biology teacher's assistance. The teacher plays the role of facilitator to enable learners to develop the necessary process skills they need to solve a problem.

(e) Practical work can be used to implement a process approach and should be seen as an opportunity where learners are posed with a problem that will enable them to be creative in finding solutions for the problem. Life-science themes can represent problems or needs of the community and the individual, and can successfully be used in a problem-solving approach when teaching biology. To encourage learners to solve problems through inquiry, it is necessary that the problem is relevant and challenging to the learner.

(f) Teachers are not always trained to conduct experiments. South African subject specialists believe that teachers should receive pre-service and in-service training to use different methods and strategies to implement a process approach.

(i) Pre-service training

With the implementation of the OBE system and with a process approach in mind, a national strategy for teacher training should be developed and improved and provision should be made for follow-up support. Student teachers should be trained to develop, initiate, conduct or evaluate the development of process skills within learners. It is believed that if pre-service student teachers engage in process skill activities, they may remember and understand these activities and may in turn implement such activities in their classrooms.

The researcher is of the opinion that student teachers should not only be trained by teacher training colleges and universities, but also by NGOs. Universities, colleges and NGOs should work together to train biology teachers effectively. Student biology teachers can be trained and evaluated according to the outcomes of the NQF. A credit can be awarded to a student-teacher as soon as he/she has reached an outcome. All these credits awarded at either a college, university or NGO can contribute to a certain outcome. The emphasis is thus on the competence of the biology student teacher to be able to implement a process approach and other changes.

(ii) In-service training

The different education departments should implement ongoing biology teacher training programmes which will equip teachers with the necessary knowledge, attitudes and skills to enable them to develop a supportive classroom environment, where the new education system and a process approach can be implemented.

- For biology teachers to implement a process approach successfully and with a degree of confidence, there is a need to guide them to do so. However, in-service training is very expensive. The growing economic problems in South Africa can possibly be combatted by joining four or five schools with a senior biology teacher as a 'mentor'. The mentor will be responsible to supply other schools with ideas and assist them in overcoming any problems they may encounter. The advantage of such a mentor will be that various biology teachers will be in contact with one another, where they can exchange ideas without further increasing the economic burden in South Africa.

- During in-service training, biology teachers should be motivated to attend workshops (for which they receive credit), symposiums, conferences and should read subject journals, to stay abreast with the latest teaching approaches, changes and new information.

- Biology teachers should not only be provided with theoretical documents of changes that should be implemented, but also with concrete examples on how to create such learning activities when teaching.

- Regular support visits of subject facilitators/researchers to assist teachers in the implementation of a process approach can promote good working relations between teachers and subject experts.

- It is believed that training and practice in the implementation of the recommended teaching and learning strategies must be emphasised. Furthermore, biology teachers must be encouraged and motivated to modify these strategies to suit their needs. Together with the implementation of these teaching and learning strategies, there is a need to emphasise alternative assessment strategies.

- Biology teachers will have to improve their content knowledge of biology. This implies that biology teachers will have to be familiar with content knowledge which goes beyond the content of the biology curriculum.

- When training biology teachers a hands-on approach should be followed. Many teachers state that they do not do practical work because of a lack of facilities at school, which in some cases is not always true. The biology teachers should be encouraged to be creative and innovative if no apparatus is available. The use of innovative ideas should be fostered by the teacher and training should provide opportunities for teachers to be innovative when conducting experiments.

- Those departments which are responsible for the training of teachers should work co-operatively to enhance biology education. It will, for example, not help if a training institution trains teachers to use a process approach when teaching biology, while education departments do not recognise the importance of a process approach in the teaching of the biology curriculum.

(g) During in-service and pre-service training of teachers, learners' different cultural backgrounds should be emphasised so that the teacher will understand the manner in which learners' interests can harmonise or conflict with science.

9.5.2 It is recommended that factors which may influence the implementation of a process approach to a great extent should be addressed in biology education

9.5.2.1 Motivation

Table 7.8 setting out some findings of the research, indicates that biology teachers claim that the secondary biology curriculum is discipline-based, content loaded and largely irrelevant to the majority of learners who will not further their studies in a biology related field. Presently the preparation for the Senior Certificate Examination is driving subject curricula. Some educationists and subject specialists believe that the biology curriculum for the senior secondary phase is overloaded with facts, and are of the opinion that this cause some of the biology teachers to concentrate merely on the transmission of information while the development of important process skills such as observing; formulating of hypotheses; experimenting; drawing of conclusions and others, is neglected. If teachers are trained in the methodology of a process approach and apply these methods when teaching biology, the curriculum need not be disciplined-based, irrelevant and content loaded.

At a time when biology can and ought to be of the best service to humankind, we may find that the biology curriculum is loaded with information that has little potential for application. It is believed that learners are faced with content which is still mostly irrelevant and not applicable in real life situations (although the Grade 8 and 9 curricula have been changed). Of the sampled teachers for this research, many HD and HA schools' teachers responded that biology curricula in some grades are still rigid, lengthy and results orientated. Furthermore, a lengthy curriculum, large classes and time hamper the effective implementation of a process approach.

The researcher is of the opinion that the gap that exists between the contemporary biology curriculum and the demands of a biology technology-oriented economy should receive attention, since irrelevant content also affects learners' attitude towards biology as a subject. Irrelevant content and the decrease of learners in biology, go hand in hand.

From experience of the researcher in Black education and the widely held beliefs of South African biology educators, many biology teachers struggle to teach effectively because of the high teacher-learner ratio (1:60 plus). Although certain schools might struggle with large classes, some principals are also exacerbating this problem by combining classes into large groups to combat the shortage of teachers in the school and to provide teachers with more free periods. Other factors believed to hamper successful implementation of a process approach are a lack of copying facilities; a shortage of textbooks; no water and electricity supply; underqualified teachers and not enough school buildings in some of the HD schools.

The qualifications of biology teachers can be regarded as another critical problem in biology education. The lack of interest in biology and the high failure rate can sometimes be related to inadequate teacher training, the decrease in qualified and competent biology teachers and a poor implementation of innovative ideas.

The most efficient method to improve the quality of teaching and learning will be to upgrade the teacher-training programmes. In-service and pre-service teacher training demands intensive attention to combat the shortage of qualified biology teachers.

The change to *Curriculum 2005* and the implementation of a process approach, will need more in-service training of biology teachers and teachers who are willing to work very hard. Adequate support in terms of financial resources must be offered to biology teachers in the form of in-service training so that they can assist learners to develop the skills they need to learn for life. The reasons why the implementation of *Curriculum 2005* had to be reviewed can be related to insufficient teacher training and co-ordination, in the new system.

9.5.2.2 Implications

This recommendation to address some of the factors that may hamper the successful implementation of a process approach, will have the following implications for biology education:

(a) The problem with large classes

(i) The economical shortages and the increasing population in South Africa cannot be ignored. As population growth and shortage of funds may result in large classes, distance education should be considered. Through distance education a teacher could guide large groups of biology learners cost effectively and can also provide in the need of individualised study. Individualised study can be provided by including clear outcomes, learner activities, self-assessment materials and opportunities for periodical feedback or on demand. Media such as books; self-instructional kits; films; computer-assisted learning and others may work consistently better than traditional teaching.

(ii) The strategies to implement a process approach and *Curriculum 2005* emphasise group work and social interaction. Leaders can be selected in each group to assist slower learners in that group. Learners can assist and assess one another in each group. The 'creativity' of the teacher will determine to what extent the strategy outlined above, will be successful in overcoming the problem of teaching large classes. As the infrastructure for schools differ, especially when comparing HD schools to HA schools, it is not possible to outline a single solution to overcome the problem of large classes.

(iii) Biology teachers should specifically be trained to handle pedagogical-didactic situations with large classes. For example teachers should be trained to do practical work with large classes or know how to create a relationship of trust with learners when using a process approach.

(b) Alternatives should be found to replace expensive laboratory facilities and equipment

Because of the tight budget and financial constraints of the Department of Education, it may not be possible to address the lack of laboratory facilities in the foreseeable future. As a laboratory is not a necessity to implement changes, teachers should be encouraged to be creative and find alternative ways to do practical work. For example: a single classroom in a school, can be used as a laboratory and equipped with home-made apparatus. The timetable should allow learners to visit this laboratory classroom once a week, where they can do practical work and design new equipment for experiments. Learners can do projects where they design experiments at home as part of their assessment. To partly combat the financial problem everyday objects can be used and to save time videos, and even computer simulations (in schools that can afford them), can be used to demonstrate dangerous and lengthy experiments.

Simple equipment, that is cost effective, can be used in both HD and HA schools. These materials may contribute to a better understanding of the experiment. Furthermore, as equipment can be built at the school using locally available or scrap materials, it can easily be repaired or replaced. Home-kits can also be considered where learners do all experiments on a shoestring (especially Grade 12 learners). Teachers can also work with nearby employers or farmers to demonstrate scientific principles in traditional and new technologies. Fieldtrips may provide learners with experience and insights about local problems and equipment.

(c) The language barrier and social cultural differences of learners should be considered when implementing a process approach

As the majority of learners are not educated in their mother-tongue, it is important that curriculum developers consider the different backgrounds and underlying beliefs of learners. Learners may only understand scientific concepts once they are familiar with unspoken expectations, and the terminology of biology.

(d) There is a call for a new flexible and relevant biology curriculum

The biology curriculum needs to be reassessed and reconceptualised with regard to flexibility. To fulfil the needs of learners the biology curriculum should be flexible, dynamic, responsive to rapid changes in matters concerning work, morals and life and choices in recreation. As far as relevancy is concerned the biology curriculum should include more of the cultural experiences of Black learners to enhance their success in Biology education.

(e) A flexible timetable is needed

'Flexi time' on the time table is also called 'notional time', which allows schools to allocate time, resources, staff and organisation to activities and issues of general importance for the implementation of a new approach (Gauteng Education Department 2000b:4).

The school-day should be organised to give learners with diverse styles and tempos of learning maximum learning opportunity and teachers time for preparation of materials and to attend workshops on the development of process skills and other developmental programmes. For example an extended school-day could include activities such as homework, extra-mural activities, extra-curricular activities and extra classes for learners learning at a slower rate. By allowing notional time for maximum flexibility in terms of teaching and learning, teachers should become acquainted with the new approach and ensure that all learners develop the skills needed.

(f) All stakeholders should participate in the development of a process approach.

All stakeholders need to be motivated to participate in the development of a process-oriented biology curriculum, by exchanging innovative ideas. The inputs of biology teachers and biology specialists are most valuable for curriculum development, since they are to a great extent the implementers of changes in the curriculum. Teachers who are able and willing to implement changes are requested to assist with the implementation of a process orientated biology curriculum.

(g) The contribution of the principal, biology teacher and parents as role players in the implementation of a process approach

(i) The role of the principal

The principal can be considered as one of the main role players who determines the successful implementation of a new approach. The principal needs to create a positive atmosphere at a school, in order to enable learners to develop process skills. An environment should be developed where learning and the development of process skills can take place. It is therefore important that the principal should change his/her organisational leadership and management styles, structures and procedures; staff development and technical support, in order to assist the successful implementation of a process approach.

A positive climate can further be created by discussing and motivating the development of process skills with the teachers and the parents. Several experts can be invited to deliver inputs on how these skills can be developed. Conferences, workshops and symposiums can be attended and a team can be selected to collect input from different stakeholders including parents.

(ii) The role of the biology teacher

Biology teachers are in an ideal position to promote the development of process skills. To be able to use a process approach successfully, consideration must be given to teaching and learning methods, assessment strategies and the instructional environment.

The biology teacher serves the role of facilitator as he/she guides learners while investigating or designing experiments. In biology education the teacher is the agent that can either prevent or promote negativity in the biology classroom. It is, therefore, important to understand what motivates and demotivates teachers. Teachers who battle to teach Grade 12 learners can make use of a mentorship scheme that gives learners space to grow, to observe and to flourish. Universities, technikons and various NGOs in the biology field are well-placed to assist teachers with mentors. Since biology education is critical for South Africa, an adequate number of committed and creative teachers is a necessity in order to develop a skilled nation. The biology teacher is in a position to either amplify or negate the implementation of a process approach.

(iii) Parent involvement

This study indicates that parental involvement in education can be considered as a factor that could encourage the development of learners' process skills (vide Table 7.8). Of the sampled teachers 43.3%(13) of HD schools and 36.65%(18) of HA schools indicated that parental involvement can contribute "to a great extent'. The South African Government encourages parents to become active participants in their childrens' education. This involvement can also help to lighten the biology teacher's load. Teachers often have to contend with classes of more than 40 learners, making it impossible to attend individually to each learner. Parents and caregivers can help to address this situation. Grandparents, parents or caregivers in different cultures, can be invited to the school to tell learners about their experiences in the past (diseases, environmental problems and others).

Partnerships between parents and biology teachers are important for the successful monitoring and implementation of a process approach. These partnerships can be facilitated by designing effective development programmes for biology illiterate parents in order to enable them to participate in the development of their childrens' process skills. Skilled parents can also train other parents in the community, who are not able to assist their children in the development of process skills.

As secondary school biology might be the last course in this field that learners will take, it is imperative that all learners will develop the necessary skills they need for lifelong learning. The factors indicated in this research, should be considered in order to ensure the successful implementation of a process approach.

9.6 SUGGESTIONS FOR FUTURE RESEARCH IN THIS TOPIC

Research findings by Mossom (1989) and Mhlongo (1997), elucidate that the development of learners' process skills are important to enable learners to learn for life. The empirical research (Chapter Seven) of this study, and interviews conducted with education specialists indicate that several factors such as: large classes; the language barrier; lack of infrastructure; insufficient resources and a lengthy syllabus may influence the implementation of a process approach. Therefore, it is important that factors outlined in Chapters Seven and Eight be duly considered before implementing a new approach.

As the successful implementation of a process approach will largely depend on the biology teachers as implementers, adequate teacher training and motivation of in-service teachers, can be considered as an important field for further research.

9.7 SUMMARY

The literature study points out that all learners need to acquire a functional biology education that will benefit the individual and the community. The biology education system should change to a more learner-centred approach where learners are provided with opportunities to develop skills that will enable them to acquire and apply knowledge in real life situations.

In order to implement a process approach, it is important that factors which prevent implementation, be identified. The main focus in this study is to determine the factors which a sample of South African teachers' believes could influence the successful implementation of a process approach in biology education. The empirical research confirms the findings of the literature study. Factors such as the biology curriculum; infrastructure and biology teaching methods, influence the implementation of a process approach.

The successful implementation of a process approach will largely depend on:

- The use of a flexible biology curriculum, which will enable learners to learn for life.

- Improvement of infrastructure for biology education to provide in all learners' needs, especially those who are not receiving any biology education and those who leave school at an early age.

- A variety of teaching and assessment methods, which should be used to facilitate the development of learners' skills, in order to enable them to learn for life.

- Adequate training and support of biology teachers to enable them to implement a process approach.

The principal, biology teachers and parents as role players, will have a definite influence on the successful implementation of a process approach. There is an explicit relationship between the role players and a process approach.

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11 APPENDICES

Appendix A1: Letter to biology teachers

UNISA

Faculty of Education
Institute for Educational Research
Tel: (012) 429-4386

Fakulteit Opvoedkunde
Instituut vir Opvoedkundige Navorsing
Tel: (012) 429-4386

6 April 2000

Letter to Biology Teachers

Dear Biology Teacher

I am conducting an investigation on why the **process approach** has not been implemented successfully in the secondary school phase of Biology teaching.

The outcomes of the investigation should provide valuable information which may improve Biology teaching in our schools. The information asked for in the attached questionnaire is of vital importance to the study and is **urgently required**. I realise that this must be an extremely busy period of the school year but I request you kindly to take a few minutes to complete and return the questionnaire **as soon as possible**.

Please note that approval has been obtained from the Gauteng Education Department for the circulation of this questionnaire and for its completion by Biology teachers.

The information you provide is confidential and your anonymity is ensured as your name appears nowhere on the questionnaire.

Please return the completed questionnaire **before 26 April** in the stamped, self-addressed envelope enclosed.

Your participation in this survey is highly valued and appreciated!

Yours faithfully

T de Jager (Researcher)

Prof GD Kamper (Academic advisor)

PO BOX/POSBUS 392, PRETORIA 0003, SOUTH AFRICA/SUID-AFRIKA ☎ (012) 429-3111 • INT +27+12 429-3111 • FAX/FAKS (012) 429-3221

Appendix A2: Questionnaire to biology teachers

Section A: General Information

For office use or

Note: This information is required for background information only.

The names of individual teachers and / or schools will not be published.

Please encircle the number which corresponds with your answer, e.g. (3)

☐☐ (1–2)

Gender:

Male [1] Female [2] ☐ (3)

Your professional status:

Level 1 [1] Head of Department [2] Deputy Principal [3] ☐ (4)

Your qualification:

2 year Diploma [1] 3-4 year Diploma [2] B.Sc. degree [3]
Any other degree [4] ☐ (5)

Your highest qualification to teach Biology:

None [1] 2 year Diploma [2] 3-4 year Diploma [3]
B.Sc. degree [4] Any other degree [5] ☐ (6)

How long have you been teaching Biology?

1-3 years [1] 4-6 years [2] more than 6 years [3] ☐ (7)

For office use only

Section B

1. Do you know what the process approach is? (8)

1	2	3
Yes	To a limited extent	Not at all

<u>Defining a process approach</u>:

A process approach can be described as a number of processes which the learners use during biology activities (eg. conducting experiments) to develop intellectual and critical thinking skills in order to have a better understanding of the content and acquire and apply information. A process refers to the fact that the teaching of biology should be in line with what scientists do. That is, gaining information by observing, classifying, predicting, etc. The process approach, therefore, utilises the basic and integrated process skills.

2. Do you know what the **basic** and **integrated** processes are that can be developed during biology teaching? (9)

Yes 1 To a limited extent 2 Not at all 3

<u>Basic process skills</u>:

Basic skills can be described as those primary (simpler) skills that a learner develops. These skills are used from pre-primary school up to Grade 5, for example: observation (use the senses to gather information); inference drawing (make an adequate guess about an object or event based on gathered information); classification (grouping or ordering of objects or events into categories based on properties or criteria); communication (use words or graphic symbols to describe an object, action, event); measurement (use measuring instruments eg. watch, scale, thermometer, etc.); prediction (state the outcome of a future event based on a pattern of evidence); space/time relations; using numbers.

For office use only

Integrated process skills:

Integrated process skills are dependent on the learner's ability to think on a high level and to consider more than one idea at the same time. The term 'integrated' implies that various of the basic process skills can be combined to solve problems. The basic process skills are prerequisites for integrated process skills. Integrated process skills are skills needed to execute scientific experiments. These skills consists of: defining operationally (the ability to express questions in more precise terms so that the information required is clear); interpreting data (organise data and draw conclusions from it); controlling and manipulating variables (identify variables that can affect an experimental outcome, keeping most variables constant while manipulating only the independent variable); formulating a hypothesis (stating the expected outcome of an experiment); experimenting (conducting an entire experiment and interpreting the results of the experiment).

3. The table reflects a number of characteristics associated with a process approach in biology education. From your experience as a biology teacher, indicate by encircling the appropriate number, the extent to which each of the following statements **applies to your teaching.**

	CHARACTERISTICS	Always	Often	Seldom	Never	
1.	Learners choose an issue or problem to investigate during biology activities	1	2	3	4	(10)
2.	Learners do experiments	1	2	3	4	(11)
3.	Learners collect their own data during biology activities	1	2	3	4	(12)
4.	Learners form their own questions about the world around them	1	2	3	4	(13)
5.	Learners do biology projects, which involve proposing a solution to a problem	1	2	3	4	(14)
6.	Learners make their own decisions to solve a problem	1	2	3	4	(15)
7.	Learners organise data and draw conclusions from it.	1	2	3	4	(16)

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CHARACTERISTICS	Always	Often	Seldom	Never	
8. Learners design their own experiments	1	2	3	4	(17)
9. Learners become curious to acquire more information	1	2	3	4	(18)
10. Learners state the expected outcome of an experiment	1	2	3	4	(19)
11. Learners also use biology skills in other disciplines such as: English, Art, Social studies, and others	1	2	3	4	(20)
12. Learners work with fellow learners to acquire and apply information during investigations (group work)	1	2	3	4	(21)
13. Learners use their writing/composition skills (words graphs etc) to share their biology ideas with fellow learners	1	2	3	4	(22)

4. How often do you do inquiry activities (fieldwork, certain practical work, project work)?

Frequently (once a week) [1]   Seldom (once a month) [2]   Once a year [3]   Not at all [4]   (23)

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5. Indicate, by encircling the appropriate number on the scale, the extent to which the listed factors could adversely affect **your** attempts at using a process approach as a teaching strategy in secondary biology teaching. Please feel free to add to the list (in the spaces provided at the end of this list) if one or more factors which you regard as important have been omitted.

	Extent to which these factors will prevent you from implementing a process approach						
	To a great extent	← SCALE →				Not at all	For office use only
1. A lengthy syllabus	1	2	3	4	5	6	(24)
2. Large classes	1	2	3	4	5	6	(25)
3. Lack of equipment	1	2	3	4	5	6	(26)
4. Inadequate resource material	1	2	3	4	5	6	(27)
5. The need to produce good exam results	1	2	3	4	5	6	(28)
6. The discipline factor (noisy classes)	1	2	3	4	5	6	(29)
7. Mixed ability classes (different learning abilities of learners)	1	2	3	4	5	6	(30)
8. Inflexible syllabi (no space or time for teachers' own innovative ideas)	1	2	3	4	5	6	(31)
9. Additional 'demands on teacher' (eg. increased workload, more lesson planning etc.)	1	2	3	4	5	6	(32)
10. Teachers' qualifications (eg. biology I, biology II, biology III etc.)	1	2	3	4	5	6	(33)
11. Attitude of the teacher	1	2	3	4	5	6	(34)
12. Lack of opportunities for teachers to attend workshops	1	2	3	4	5	6	(35)
13. Irrelevant content (content is not relevant to all learners' different cultural backgrounds)	1	2	3	4	5	6	(36)
14. Insufficient integration of biology with other subjects	1	2	3	4	5	6	(37)

For office use only

	To a great extent	← SCALE →				Not at all	For office use
15. Not enough assistance from parents to develop learners' process skills	1	2	3	4	5	6	(38)
16. The language barrier (e.g. English for N-Sotho learners) hampers the development of learners' process skills	1	2	3	4	5	6	(39)
17. Insufficient infrastructure (eg.electricity, desks, water etc.)	1	2	3	4	5	6	(40)
18. Outcomes for the process approach are not clearly stated by the curricula developers.	1	2	3	4	5	6	(41)
19. Teachers lack knowledge of teaching/learning strategies which promote the development of learners' process skills	1	2	3	4	5	6	(42)
20. Learners' reliance on mere memorisation of facts (rather than using skills to acquire information)	1	2	3	4	5	6	(43)
21. Insufficient lesson planning of biology teachers	1	2	3	4	5	6	(44)
22. Learner group work is neglected	1	2	3	4	5	6	(45)
23. Teacher – centred teaching	1	2	3	4	5	6	(46)
24. Teachers avoid inquiring activities such as field work/laboratory work & practical work	1	2	3	4	5	6	(47)
25. Learners fail to apply biology content to everyday life situations	1	2	3	4	5	6	(48)
26 Teachers do not create opportunities where learners can interact with instructional material (eg.conduct experiments as biologists do)	1	2	3	4	5	6	(49)
27 The principle fails to provide a supportive climate in your school to implement innovations	1	2	3	4	5	6	(50)

For office use only

Other factors:

....
....
....
....

6 For which target group is the development of process skills the **MOST** valuable? (please indicate only **ONE** of the following options)

1. For those learners who are going to study in biology related fields at tertiary institutions e.g. medicine, biology teaching, engineering. [1]
2. For those learners who are going to study in fields other than biology at tertiary institutions eg. law, commerce. [2]
3. For those learners who are not going to study at tertiary institutions. [3]
4. All three options [4]

[ ] (51)

Section C: Additional Comments

Please give your honest and frank opinion on any aspect of a process approach in biology education:

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Thanking you

T. De Jager

Appendix A3: Interview Questions

INTERVIEW QUESTIONS

	Questions
1.	Are the current biology curricula flexible and relevant to address the needs of South African citizens?
2.	What approach should be used to teach biology effectively? (with the development of learners' process skills in mind)
3.	If one considers a process approach (development of process skills) as important to teach biology effectively, why is this approach not implemented successfully in biology education?
4.	How can the factors that might hamper the effective implementation of a process approach be combated?
5.	Which methods should be used to develop learners' process skills?
6.	Are teachers adequately trained to implement a process approach?

Appendix B: Permission to conduct research

P.O. BOX 7710
JOHANNESBURG
2000

111 COMMISSIONER STREET.
JOHANNESBURG
2000

Tel: (011) 355 - 0555 Fax: (011) 355 - 0670

Researchers Particulars:

De Jager T

Institution: Unisa

Student No:

Date: 28 March 2000

Dear De Jager T

Request to conduct a study

Topic: WHY IS THE PROCESS APPROACH NOT IMPLEMENTED SUCCESSFULLY IN THE SECONDARY PHASE OF BIOLOGY IN EDUCATION

Approval is hereby granted that you may conduct a study / administer a questionnaire to Gauteng schools. Approval is with effect from 7 February 2000

District(s) where the study shall be conducted: throughout the province.

Permission is subject to the following conditions:

1. The District Director concerned is to be informed that you have received permission from the Gauteng Department of Education to conduct your research in the specified GDE school/ district / region.
2. Please show this letter to the school principal and the chairperson of the School Governing Body (SGB) as proof that you have received the Department's consent to carry out the research.
3. A letter / document which sets out a brief summary of your intended research should please be made available to the principal of the school concerned.
4. Please obtain the goodwill and co-operation of the principal, chairperson of the SGB, learners and educators involved. Persons who offer their co-operation will receive no special benefit from the Department, while those who prefer not to participate will not be penalised in any way.
5. You must conduct your research after school, and the normal school programme should be interrupted as little as possible. The principal must be consulted as to the times when you may carry out your research.

6. The names of the school, learners and educators may not appear in your dissertation without their consent.
7. Please supply the Department via the Research Unit with a bound copy of the report. You may also be requested to give a short presentation on your findings
8. Please supply the Director in whose district the school (s) is/are located with a brief summary of your findings.
9. You must obtain the consent of parents to involve their children in your research. This is the researchers responsibility.

The Department wishes you well with this project and looks forward to hearing from you in due course.

Regards

Lekhotla Mafisa
Research Unit.

The research shall be carried out throughout the province covering the following Regions

Central: 36 secondary schools
North: 34 secondary schools
South: 20 secondary schools

GAUTENG DEPT. OF EDUCATION
HEAD OFFICE
2000 -03- 2 8
PRIVATE BAG 7710
JOHANNESBURG 2000
GAUTENG DEPT. VAN ONDERWYS