HOW DO TEACHERS AND LEARNERS NAVIGATE THE TERRAIN OF ECOLOGY AND WHAT ARE THE ASSOCIATED CONCEPTUAL UNDERSTANDINGS?

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophiae in the Department of Biodiversity and Conservation Biology, University of the Western Cape

By

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DEDICATION

To Lincoln, without whose support and encouragement none of this would have been attempted.

HOW DO TEACHERS AND LEARNERS NAVIGATE THE TERRAIN OF ECOLOGY, AND WHAT ARE THE ASSOCIATED CONCEPTUAL UNDERSTANDINGS?

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KEY WORDS

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Curriculum

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Scientific literacy

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Classroom conditions

Teaching strategies

Poverty

Teacher qualifications

ABSTRACT

HOW DO TEACHERS AND LEARNERS NAVIGATE THE TERRAIN OF ECOLOGY, AND WHAT ARE THE ASSOCIATED CONCEPTUAL UNDERSTANDINGS?

This thesis relates the teaching of ecology in schools to the requirements of the National Curriculum Statements, Grades R-9 and Grades 10-12, for Natural and Life Sciences. It examines the conceptual understanding of the learners to determine their level of bioliteracy. The effectiveness of various teaching strategies in enhancing bioliteracy is considered.

The study was a case study involving classroom observations of Grades 4 to 7 at a primary school and Grades 8 to 11 at a high school in the Western Cape of South Africa, and the administration of a misconceptions questionnaire to learners in Grades 8 to 11. The Department of Education did not allow researchers into the Grade 12 classes. To counter this, the misconceptions questionnaire was also administered to first-year Life Science students and to students in one second-year course in the Department of Biodiversity and Conservation Biology. It was administered to a small sample of the Postgraduate Certificate in Education (PGCE) students (prospective teachers) at the University of the Western Cape, in order to determine whether misconceptions would be carried into their teaching. In-depth interviews which focussed on the particular student's misconceptions were used to verify the misconceptions which the first-year students held.

The questionnaire revealed that learners lacked an understanding of photosynthesis and respiration, which forms the basis for an understanding of food chains and energy flow within an ecosystem. Learners were confused about ecology and did not understand basic concepts. The misconceptions held in high school carried over to university, as shown by the fact that the first-year Life Science students, tested before they had had any lectures, still held many of the misconceptions that were found among the high school learners. A few second-year students still held

misconceptions, but their understanding of photosynthesis and respiration was better than that of first-year students. The questionnaire also revealed that learners lack language skills. Good language skills are necessary for the development of scientific literacy.

Three of the seven teachers whose classes were observed admitted to finding it difficult to teach ecology. One of them suggested that the Department of Education provide special training to teachers in this area of teaching.

Issues relevant to South African problems were not addressed in any of the classes observed. Too little time is allocated to the teaching of ecology to allow for any discussion of social issues relating to this subject. Time, resource constraints, and a lack of training in teaching ecology make it impossible for teachers to fulfil the requirements of the curriculum. Grade 10 learners were required to identify abiotic and biotic factors operating in a local ecosystem, and to describe the trophic relationships present. Grade 11 learners were required to study and report on one local example of human influence on the environment. These requirements were not met. While teachers were prepared to take learners out of the classroom to study ecology, some of them were not able to do so because of extremely large classes and associated problems.

The results of the misconceptions questionnaire for the PGCE students revealed that a high percentage of them had very little understanding of ecology and that they held several common misconceptions, despite having completed a degree which qualified them to teach Life Science or Natural Science in high school. This study demonstrated that more attention needs to be given to the proper training of Life Science teachers, and to instruction in practical work and fieldwork in the Life Sciences.

DECLARATION

I declare that *How Do Teachers and Learners Navigate the Terrain of Ecology and What are the Associated Conceptual Understandings?* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Rosemary Ruth Raitt November 2011

Signed: ...Raitt...............

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CHAPTER 1: INTRODUCTION

1.1 Background of study

Before the introduction of Outcomes –Based Education (OBE), South African teachers used to teach in the traditional way that maintained a distance between the learner and the outside world and its problems. The teaching strategy was what Wells and Arauz (2006) describe as "transmissionary mode". Then OBE was introduced, and teachers were expected to become "facilitators of learning" (Department of Education, 1997). They were supposed to encourage cooperative learning and have a variety of teaching strategies that could be used (Killen, 2000). Learners were to confront problems facing South Africans (DoE, 1997a). This change required a high degree of flexibility from teachers who were used to teaching in a prescriptive system where "facts" were imparted to learners and received by learners passively, if not in silence.

This study was started in 2007 when schools were using the National Curriculum Statement of 2003 (Department of Education, 2003). This has since been replaced by the New Curriculum (DoE, 2007). The curriculum will change yet again at the beginning of 2012, when the Curriculum and Assessment Policy Statement (CAPS) will replace the New Curriculum (Department of Basic Education, 2010). In 2009 the Department of Education was separated into the Department of Higher Education and Training and the Department of Basic Education. A comparison of the outcomes of the three curricula is set out and the implications discussed in Chapter 3.

1.2 Rationale

The background given above indicates that the curriculum requires important issues to be raised in the classroom, yet we do not know if this is happening. Plonczak (2008) believes that if we put issues in the political and social contexts in which they occur, learners would be able to engage with them far more easily than they can engage with the current abstract and decontextualised curriculum content.

This research aims to look at what actually happens in the classroom when ecology is taught.

- What "South African issues" are raised in the curriculum?
- What teaching strategies are used to teach ecology?
- What do teachers regard as of importance in ecology?
- How would the learners prefer to learn ecology?
- Can teachers handle fieldwork?

1.3 Research questions

The purpose of this study is to address the following questions:

1 How do teachers and learners navigate the terrain of ecology and what are the associated conceptual understandings?

2 Is the teaching of ecology addressing important issues relevant to South African problems, as suggested in the curriculum?

3 What is the range of teaching strategies used by teachers to teach ecological concepts, and do these strategies develop ecological concepts adequately?

1.4 The significance of this study

More and more voices are being heard warning of severe problems if humans continue to ignore the plight of this planet (Osborn, 2003; Stern, 2006). The Executive Summary of the Stern Report outlines the projected impact of global warming on developing economies. It warns that climate change threatens food production, access to water, and the health of people around the world (Stern, 2006). To meet these challenges we need an ecologically literate population capable of demanding ecologically responsible decisions from policy makers. The only way to achieve this, if it is at all possible, is by education. It is thus essential to determine what is actually happening in our classrooms. This study aims to provide some information on the way in which ecology is taught. While it is not possible to generalise from a qualitative study, this study can indicate areas that need further research.

1.5 Delimitation of this study

This study was a case study using two schools, one primary school and one high school, and a sample of first-year Life Science students at the University of the Western Cape.

1.6 The structure of this thesis

Chapter 2 sets out the reasons why the study of ecology is important, and the impact of the free market economy on the environment and on schools. It notes the problems faced by teachers trying to fulfil the requirements of the curriculum, and shows why teaching ecology as required by the curriculum is important.

Chapter 3 gives the conceptual framework of scientific literacy and bioliteracy that are necessary for ecologically responsible actions. It also shows the move away from an environmental focus in the curriculum.

Chapter 4 explains the methodology of the study and shows how rigour was maintained. It explains why a case study format was used, and describes the instruments used to collect data.

Chapter 5 gives the results of classroom observations in the primary school and gives a 'thick description' of the school. It illustrates some of the problems experienced when doing research in schools.

Chapter 6 reports on the results of classroom observations and the administration of a misconceptions questionnaire in Grades 8 to 11. The results show the low levels of bioliteracy that exist in schools.

Chapter 7 reports on the results of the administration of the misconceptions questionnaire to students in the Department Biodiversity and Conservation Biology doing Life Science first and second-year courses, and on the Postgraduate Certificate of Education students who completed the questionnaire. The findings show that completing a university degree does not guarantee bioliteracy.

Chapter 8 gives a summary of the answers to the research questions, and discusses the implications of the findings.

Appendix A – Letter of permission to do research in schools
Appendix B – Results of pilot test
Appendix C – Observation schedule
Appendix D- Teacher's consent form
Appendix E - Tests
Appendix F - Revised National Curriculum Statement for the Natural Sciences *Senior Phase* (Grades 7 to 9).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter will look at what is included in "ecology" and "environmental education" and why it is important for learners to have an understanding of both. Some of the problems impacting on ecology are discussed briefly. Ecosystem services and some of the effects of natural areas on human beings are noted. Decisions made on environmental issues are put in the political context. Factors that influence such decisions, and why it is important for learners to be made aware of behind-the-scenes influences are discussed. Sustainability, the changes that need to be made, and factors that impede change are then considered. Some of the problems facing South African schools will be discussed to draw attention to why it may be difficult to teach ecology.

2.2 Ecology and Environmental Education?

What is ecology? Ecology is the

> study of the interactions of living organisms with one another and with their non-living environment of matter and energy; study of the structure and functions of nature (Miller, 2002:G4).

This definition is very convenient for teachers who do not wish to become involved in the messy problems resulting from human impacts on the environment, because it appears to exclude humans since we do not usually include ourselves as part of "nature". It is difficult to see how we came to separate ourselves from "nature" and "the environment", when we cannot exist without either of them.

Ingold (2000) mourns the "fault" which causes Western thought and science to divide the world into two, humanity and nature, a fault which Rees (1997) refers to as "scientific apartheid". To Ingold (2000), the recognition of the fact that human beings are biological organisms living within the environment and products of evolution means that we are as much shaped by our interactions with the environment as we shape our environment. Our environment is constituted by the relationships of organisms within it, thus our social relations are a subset of ecological relations (Ingold, 2000). This fits in with Rosenberg's (2004:146) view of what is encompassed by Environmental Education – "the inter-relations between our social and bio-physical worlds". The focus should be on environmental issues that human beings face because of their use of natural resources, and how to deal with those problems and prevent future problems (Breiting & Mogensen, 1999).

Showing students how our social world impacts on the physical world is a challenging task for teachers, particularly if Breiting & Mogensen's (1999) suggestions are taken seriously. They believe that every environmental issue involves conflicting interests in the use of natural resources. These issues do not disappear when one gains knowledge of them. Issues emerge at the individual level when there is a conflict between needs and wishes. They emerge at the social level as clashing interests between various groups, and at society level, for example, between political decisions and economical mechanisms or market forces. The pupil's work in Environmental Education should involve finding and exposing the conflicting interests and showing how they affect our future (Breiting & Mogensen, 1999). For the average South African teacher, coming from traditions that value acceptance of the right of those in authority to make decisions without being questioned, these ideas are frightening.

The New Life Sciences Curriculum for Grades 10 – 12 (DoE, 2007) has four strands which form the curriculum, and one of them is "Environmental Studies", which includes the effects of pollution and the impact of human activities on ecosystems. This study will therefore not use the limited definition of ecology. It will include all aspects of the curriculum in the strands "Environmental Studies" and "Diversity, Change and Continuity", which include considerations of the social impacts of science. The proposed curriculum to be implemented in 2011 has the same four strands (Department of Basic Education, 2010).

The problem with attempting to include considerations of the social impacts of science is that these are very difficult to deal with in a "science" classroom (Jensen, 2004). Jensen (2004) notes that biology, chemistry and physics have been in charge of environmental education in schools. In these subjects the scope of a problem is dealt with but no indications of the actual causes of the problem are considered. Various experiments can be done in the laboratory to measure exhaust gases, for example, but these leave students with the idea that increased energy consumption can be blamed on motorists. The conditions which made society so dependent on cars are not considered, though they are the actual cause of increased energy consumption. This approach leads to what Jensen (2004) refers to as "action paralysis" and feelings of powerlessness. He argues that, to counter our inability to act on problems, we need to bring in the social sciences to show us how we should act on problems and what possibilities for action we have. It is this action approach that I believe the Life Sciences Curriculum envisaged with its emphasis, in Learning Outcome 3, on social issues embedded in the content.

2.3 Research on misconceptions in ecology

Misconceptions hinder the acquisition of new knowledge (Stamp, Armstrong & Biger, 2006). There has been a great deal of research on misconceptions, which shows that even students who have majored in a subject or pre-service teachers may still hold misconceptions about that subject. This is true for ecology as well. (Barman & Steyn, 2008; Eisen & Stavy, 1988).

An understanding of photosynthesis and respiration is essential to understanding ecology (Çepne, Taş & Kőse, 2006; Eisen & Stavy, 1988). In the pre-test of a study using Computer-assisted Instruction Material on Grade 11 learners, Çepne *et al* (2006) found that 35% of the learners in the experimental group believed that animals breathe in oxygen and breathe out carbon dioxide, while plants breathe in carbon dioxide and breathe out oxygen. This percentage was not significantly reduced in the post-test, where 31% still held the misconception. The misconception that photosynthesis is the respiration of plants was reduced from 34% in the experimental group in the pre-test to 8% in the post-test. In the pre-test 12% believed that respiration occurs in the lungs and is solely the process of gas exchange. This misconception was not evident in the post-test.

Köse's (2008) study that was conducted with third-year college students found that 40% of them still had misconceptions about photosynthesis and 58% of them had misconceptions about respiration. Köse attributes these to misconceptions held by teachers, and to analogies like "forests are the lungs of the planet". To counter this misconception Flores & Tovar, (2003), found that it was necessary to teach general processes like respiration or reproduction from multicellular organism to cell. This would mean that one started with the general need for respiration in the organisms, then progressed to where it occurs in the cell and pointed out that both plant and animal cells have mitochondria.

Chiromo's (2001) study identified misconceptions held by 'O' Level students in Zimbabwe. He used a multiple-choice test to determine misconceptions held by students, and then did face-to-face interviews to confirm his findings. Only 48% of the students in the study were aware that food chains start with producers. Seventy-three of these students did not think that they would be affected if all producers in a food web died. Thirty-six percent of the students were unaware that nitrogen is used by plants in protein synthesis.

These studies indicate that misconceptions in ecology are common. Teaching needs to be directed at enabling learners to confront their misconceptions. Other studies on misconceptions in ecology will be discussed in Chapter 4, when the selection of items for the questionnaire is discussed.

2.4 The relevance of ecology

Natural systems are being seriously disrupted, and it is time to look at curbing over-consumption of resources, both non-renewable and renewable. Rees (1997: 64) warns

> For the first time since the dawn of agriculture and the possibility of geographically fixed settlements 12 000 years ago, the aggregate scale of human economic activity is capable of altering global biophysical systems and processes in ways that jeopardize both global ecological stability and geopolitical security.

A plethora of peer-reviewed scientific articles warn of the negative impact of human activities on the environment. These articles range from warning of the impact of disruption of biogeochemical cycles (Austin, Piñeiro, & Gonzalez-Polo, 2006; Rees, 1997; Kinzig & Socolow, 1994) and articles listing factors such as damage to the ozone layer, increase in acid deposition and pollution (Corson, 1995), to the Stern Report which attempts to spell out the impacts of global warming on countries, particularly developing countries (Stern, 2006).

We face numerous problems but, because the focus of this thesis is not on the problems but on teaching, only the following selection of problems will be discussed: pollution, loss of biodiversity, and lastly, overarching all of these, poverty. The services that are provided by a smoothly functioning ecosystem will also be discussed.

2.4.1 Pollution

The effects of pollution are widespread. The impact of pollution in only three areas will be discussed: global warming, decrease in stratospheric ozone, and endocrine disruptors.

2.4.1.1 Global warming

There are those who claim that global warming is not happening (Boykoff & Boykoff, 2004; Dispensa & Brulle, 2003; Newell & Paterson, 1998). To combat global warming we would need to make drastic changes in the way we live (Oskamp, 2000; Jamieson, 1992), and this is one of the reasons why people deny that global warming is happening. However, scientists have no serious doubt that global warming is occurring (Boykoff & Boykoff, 2004; Ball, 1999). The carefully researched exposition of the urgent need for change and what that change should be by Monbiot (2007), leaves one in no doubt that climate change is happening fast, but that there is not the political will to make changes (Osborn, 2003; Mortenson, 2000).

While the greenhouse effect is a natural effect which helps heat the troposphere and the earth's surface, we have increased the concentration of greenhouse gases in the atmosphere beyond what we need, to the point where they are causing global warming (Miller, 2002). The causes of this increase in greenhouse gases are many and varied. For example, farming is a key contributor of the greenhouse gases methane and nitrous oxide (Gregory, Ingram & Brklacich, 2005; Miller, 2002). The production and use of synthetic fertilisers produce greenhouse gases (Austin *et al*, 2006; Miller, 2002; Kinzig & Socolow 1994). Probably the most widely recognised source of greenhouse gases is the burning of fossil fuels for transport, industry, and the generation of electricity (Miller, 2002; Brundtland, 1987). Seventy-five percent of South Africa's primary energy comes from coal and about 92% of its electricity supply (van Schalkwyk, 2005), and he warns that South Africa emits a rather high percentage of greenhouse gases for its size.

Global warming will bring many other changes that have diverse and unexpected consequences (Stern, 2006; Jamieson, 1992). For example, with an increase in the temperature comes an increase in the range of the vectors for such diseases as malaria and bilharzias, whose ranges could then be extended to areas which have been free of both diseases (Stern, 2006). Reiter (2001), however, maintains that the effects of global warming are far more complex than suggested by a direct relationship between increase in temperature and wider distribution of mosquitoes. He believes that the changes in the distribution are not so easy to predict. Another effect of global warming is rising sea levels. The tiny island of Vanuatu, (formerly New Hebrides), a former colony of Britain and of France, is already experiencing the results of rising sea levels (Shibuya, 1997), and has been trying without success to draw the attention of the rich nations to its plight.

2.4.1.2. Decrease in stratospheric ozone

It is often difficult for people to understand the effects of ozone because the effect depends on where in the atmosphere it is found. In the stratosphere, which extends to about 17 – 48 kilometres above the earth, ozone is essential for life on earth. This ozone keeps about 95% of ultra-violet radiation from reaching the earth's surface, thereby allowing life to exist on land by protecting humans from sunburn, skin and eye cancer, cataracts, and damage to the immune system (Miller, 2002; Longstreth, 1991). Even low levels of ozone in the troposphere, which is the innermost layer of the atmosphere, cause damage to plants and also to our respiratory systems (Miller, 2002).

Some human activities decrease ozone in the stratosphere and increase ozone in the troposphere (Miller, 2002; Longstreth, 1991). One of the major causes of ozone depletion has been the release of chlorofluorocarbon (CFCs) compounds into the atmosphere (Miller, 2002; Longstreth, 1991). CFCs were used as refrigerator coolants, aerosol propellants, cleaners for electronic parts, and bubbles in plastic foam. The use of CFCs has been phased out. However, ozone-depleting chemicals will remain in action for eleven to twenty years (Miller, 2002).

2.4.1.3 Endocrine disruptors and antibiotics

There are approximately 80 000 chemicals registered for commercial use, and endocrine disruptors (EDCs) are found in pesticides, fertilisers, pharmaceutical, medicines, cosmetics, flame retardants, and personal care products (van Vuuren, 2008). There are many ways in which disruptors affect the endocrine system: they may bind to the natural hormone receptor sites and thus prevent the natural hormone from binding to the site; they may inhibit the synthesis of the hormone; or they may disrupt transport and metabolism of the hormone (van Vuuren, 2008; Bigsby, Chapin, Daston, Davis, Gorski, Gray, Howdeshell, Zoeller, & vom Saal, 1999).

While pesticides and various industrial chemicals have been studied, insufficient research has been done on pharmaceuticals (such as contraceptive pills) and personal care products (PPCPs) with reference to their effects on the ecosystem (Daughton & Ternes, 1999). PPCPs get into the environment via sewage systems and runoff in wet weather, and are widely distributed. Many of the bioactive ingredients survive treatment in sewage treatment facilities but they are present in such small quantities that they are ignored, despite the fact that very small amounts have an effect on the endocrine system. Many PPCPs are persistent in the environment, and we have little knowledge of exactly how they affect the environment (Daughton & Ternes, 1999).

Sperm counts in men have decreased over the last 20 years (Beeby & Brennan, 2008; Oskamp, 2000; Carlsen, Giwercman, Keiding & Skakkebæk; 1995). There is an increase in testicular cancer, cryptorchidism (absence of one or more testes due to the failure of testis to move down into the scrotum) and hypospadias (the urethra opens anywhere along the penis), and it is suggested that these are caused by an increase in oestrogen-like substances in the environment (Carlsen *et al*, 1995). High concentrations of triphenyl phosphate, a flame retardant, are associated with a decline in sperm concentration, and chlorpyrifos-methyl is associated with reduced sperm motility (Meeker & Stapleton, 2010). Flame retardants are widely used and found in the house dust of most homes (Meeker & Stapleton, 2010).

Sewage from millions of homes gets discharged into the environment virtually untreated in the USA (Raloff, 2002). It is not likely to be any different in South Africa. It is clear that we are discharging chemicals into the environment faster than we can keep track of their effects on the environment, and many effects will be cumulative and thus escape detection until it is too late to trace them to their sources (Daughton & Ternes, 1999).

2.4.2 Loss of biodiversity

There is no doubt that species are becoming extinct faster than the normal background rate of extinction (O'Connor & Crowe, 2005; Miller, 2002; Pimm, 2002), but Pimm (2002) notes that there are still critics who question the evidence. The first criticism is that there is no extinction crisis. In Hawaii there are 43 species of birds known only by their skeletons, indicating that they are recently extinct because bird skeletons are very fragile and do not last long (Pimm, 2002). As far as plants are concerned, 84 of the 980 plant species in Hawaii are extinct, and 133 have wild populations that consist of fewer than 100 individuals (Pimm, 2002).

Then critics say that the extinctions are only on islands and therefore not significant because mainland populations are not threatened. This is disproved by Goldblatt & Manning (2002), who note that 60 fynbos species are known to be extinct and 1320 Cape plants are in the Red Data Book. There is an unusually high incidence of endemism in the Cape Floristic Region, with 69% of the 9030 plant species being endemic (Goldblatt & Manning, 2002), and endemic species being more vulnerable than others because of their limited range of distribution (Pimm, 2002).

Critics then point to the fact that vast areas of forest were lost in the 19^{th} century in eastern North America and only four species became extinct. Therefore, destroying the tropical rainforests is not likely to cause many extinctions. Pimm (2002) points out that so few species became extinct because most of the species have a wide distribution and could regenerate from populations elsewhere. He points out that if the South-East Asian forests had been destroyed, 585 species would have become extinct, because these 585 species are only found in those forests.

The question is then asked, "Where are the bones?" In other words, why don't we find evidence of extinct species? Pimm (2002) explains that nearly 1 million km^2 of forest are eliminated every five to ten years, and after all this habitat destruction species may survive for several decades but will eventually become extinct. He notes, "The dodo did not go extinct. Humanity bludgeoned it into oblivion" (Pimm, 2002:196).

It is human activity that is destroying habitats. One way to ensure that the maximum number of species will be saved from extinction is to identify 'hotspots' and fund their protection. Hotspots are areas that "have exceptional concentrations of endemic species and are experiencing exceptional loss of habitat" and "must contain at least 0.5% or 1,500 of the world's 300 000 plant species as endemic" (Myers, Mittermeirer, Mittermeier, da Fonseca & Kent, 2000: 854). They note that 1.4% of the earth's surface houses 44% of all plant species and 9,645 vertebrate species, and 25 hotspots contain the only remaining habitats for these plants and vertebrates.

In Britain, where an estimated 10 million breeding pairs of 10 species of farmland birds have disappeared since 1979, it has been possible to reverse the decline in numbers of the grey partridge, cirl bunting and corncrake, but it took changing of farming practice (Krebs, Wilson, Bradbury & Siriwardena,1999). Unfortunately, in many hotspots the land is held in common and, as Lovett, Quinn, Ockwell, & Gregorowski, (2006) point out, land held in common is not looked after, as each person feels obliged to maximise his/her gains from what is free.

2.4.3 Poverty

"Poverty is the major cause and effect of global environmental problems" (Brundtland, 1987:3). The problem of poverty is not just a case of not having enough money to buy what is needed. It is a social problem, an emotional problem, an economic and a political problem (Iroegbu, 2010; Mukaosolu, 2010; Maarman, 2009; Calderisi, 2007; White, Killick, Kayizzi-Mugerwa, Savane, 2001; Yunus, 1998). The number of people in absolute poverty in Africa has increased by five times more than in Latin America and twice that in Southern Asia since the 1980s. Primary school enrolments in Africa are at the same level as they were 20 years ago, at about 80% (White *et al*, 2001). Some African countries have poverty rates of up to 70%

(Mukaosolu, 2010). Yunus, (1998:47) declares that "Abject poverty is a creation of mankind, not of nature".

Many poor people are illiterate and a simple solution would appear to be free education, but there is more to education than sitting at a school desk. Poor children are undernourished (Oldewage-Theron, & Slabbert, 2010; Vorster, 2010). Poor nutrition in the uterus and early childhood impairs cognitive ability and physical development and thus makes it difficult to benefit from education, which in turn leads to decreased chances of escaping poverty. Poor nutrition affects one's personality, motivation and self image, and impairs immunity (Vorster, 2010; Olivier, 2006).

Poor people cannot afford to give their children what they need for school or allow them time and a space in which to study (White *et al*, 2001; Maarman, 2009). They cannot afford treatment during illness. Because the poor do not have access to health care a small injury can turn into a permanent disability (White *et al*, 2001). Lack of access to clean water would make home care of injuries impossible.

There is extreme inequality in South Africa. Brazil is the only country that has a more unequal society than South Africa. The top 10% of households in South Africa earn about half the total income of the country. Nineteen million people access only 11% of the total income. Rural poor tend to be invisible to the white elite, and the comforting myth exists that they are at least able to feed themselves from the land (Kalati, & Manor, 2005).

A weakening of economic and political systems in Africa in the last three decades has contributed to poverty. Twenty-eight countries are involved in conflict (White *et al*, 2001). Because of the following political factors poverty reduction has been held back:

- lack of a stable framework for growth;
- poor service delivery;

- absence of a poverty reduction strategy;
- inability to target areas requiring assistance (White *et al*, 2001);
- politicians as "political foragers and scavengers" who gather to themselves economic resources for themselves by using their political office and thereby create a "culture of poverty" for others (Iroegbu, 2010). a sentiment endorsed by Calderisi (2007) in less forceful language.

Policies for alleviating poverty should include:

- improving health, education, water supply and infrastructure (Mukaosolu, 2010; White *et al*, 2001);
- empowerment of women (Yunus, 1998);
- improving urban agriculture to enhance food security and provide employment (Oldewage-Theron, & Slabbert, 2010);
- the inclusion of a nutritional intervention in any poverty relief programme (Vorster, 2010);
- limiting population growth (Brundtland, 1987);
- reducing the gap between the rich and the poor (Kalati, & Manor, 2005; Oskamp, 2000; Corson, 1995).

The Grameen Bank in Bangladesh has shown what the poor can do for themselves if they are given access to credit. The description of the Grameen Bank that follows is based on Yunus (1998). It is a for-profit organisation that includes social awareness. Grameen has a system of "social collateral". Landless women form groups of five to receive loans. The poorest two receive their loans first. The others do not receive their loans until those two start repayment. Peer pressure is exerted if any wilfully fail to pay. There is also peer support through difficult times.

Grameen does not have to have a repayment incentive, which would add to the cost of the loan, because the group understands what is necessary to maintain credit discipline, and makes sure the loans are paid back (Yunus, 1998). No bank will give credit to the poor because the poor can offer no security, but the size of loans needed is small in comparison to the loans given to the wealthy that are often rolled-over, and governments are quite prepared to bail-out large corporations and use the excuse of saving jobs, when a series of much smaller loans would create jobs and alleviate poverty (Yunus, 1998).

To achieve poverty alleviation requires

> people who will fight for what is right, good and just; people who will work to re-fashion society along more socially-just lines; people who will work vigorously in the best interests of the biosphere (Hodson, 2003:660).

This should be the task of education (Hargreaves, 2003).

2.4.4 Ecosystems services

What are ecosystem services? According to Bolund & Hunhammar (1999:293)

> 'Ecosystem services' refers to the benefits human populations derive from ecosystems.

De Groot, Wilson & Boumans (2002) refer to ecosystem functions rather than ecosystem services because there are so many ecosystem goods and services, and this complexity needs to be reduced so that it can be evaluated. They define ecosystem function as

> the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly (de Groot *et al*, 2002:394).

Human beings tend not to value things that do not have a price tag attached, hence the need for some way of attaching a monetary value to the services offered by healthy ecosystems (Miller, 2002). The Stern report has attempted to give a monetary value to the work done by the ecosystem (Stern, 2006). This has led to disagreements among economists as to whether the 'discount rate' is correct or not (Beckerman, 2007).

Because this thesis deals with teaching and there is not the scope or depth of understanding to engage with these arguments, I mention that they exist to provide a context for the way in which they distract attention from the real need to recognise the value of ecosystem services. Bennett, Peterson & Levitt (2005:125) warn

> If the current trends continue, human demand for ecosystem services may exceed the Earth's ability to provide them.

The question then is, "What services are provided by healthy ecosystems?" De Groot *et al* (2002) lists twenty three services, and this list omits some services listed by other authors. To keep the discussion concise I will use de Groot *et al*'s four categories of "ecosystem functions". These categories are: Regulation Functions; Habitat Functions; Production Functions; Ornamental Resources; and Information Functions.

2.4.4.1 Regulation functions

These include climate regulation; disturbance regulation; water regulation and supply; soil retention; soil formation; nutrient cycling; waste treatment; pollination; biological control (de Groot *et al*, 2002). According to Raudsepp-Hearne, Peterson, Tengo, Bennet, Holland, Benessaiah, Macdonald, and Pfeifer (2010), these services have declined more than any other ecosystem services. Because the human population is increasingly urbanised (Faulkner, 2004; Ehrenfeld, 2001; Rees, 1997) with about half the world's population living in cities (Andersson, Barthel, & Ahrné, 2007; Ehrenfeld, 2001), regulatory functions will be discussed in terms of how these functions can be maintained despite urbanisation. In the countryside wetlands alone perform several regulatory functions.

Maintenance of regulatory functions in cities

Cities are known to be as much as 1 to 3 ° C hotter than the surrounding countryside (Ehrenfeld, 2001), because of the large areas covered by asphalt and by roofs, both of which absorb heat, and also because of the use of motor vehicles (Anderson, Lambrinos & Schroll, 2010; Bolund & Hunhammar, 1999; Botkin & Beveridge, 1997; Rees, 1997). The results of this "heat island effect" are that people die of heat stroke; there is an increased demand for electricity used for air conditioning; and local plants and animals are negatively affected (Anderson *et al* 2010; Botkin & Beveridge, 1997).

Parks and green areas in cities can reduce this difference through transpiration. A single large tree transpires 450 litres of water per day, which uses 1000 MJ of heat energy to drive evaporation (Botkin & Beveridge, 1997). Trees also shade houses, keeping them cooler in summer and protecting them from wind in winter (Bolund & Hunhammar, 1999). Water bodies also moderate temperature by absorbing and releasing heat (Miller, 2002; Davies & Day, 1998). It is thus clear that street trees and green spaces with water features in cities can serve to assist with climate regulation. They can also serve to control flooding. Trees in urban areas reduce run-off and prevent flooding because water is temporarily stored on the leaves and bark of the trees. The size of the reduction depends on the type of tree, with broad-leafed trees storing more water on their leaves (Xiao & McPherson, 2002). Trees filter out dust from the air (de Groot *et al,* 2002; Bolund & Hunhammar, 1999). Leaf litter and normal vegetation cover slows the flow of water, increases its infiltration into the soil, purifies and filters water, and prevents floods (Miller, 2002; Xiaogang, 2001).

Green roofs can contribute to stormwater control by holding water and slowing runoff. Anderson *et al* (2010) note that moss can absorb ten times its weight in water, thus slowing runoff considerably. Because of this green roofs using moss are particularly effective in preventing flooding.

Wetlands

Wetlands are effective flood-control agents because they spread water out and slow it down. They store and slowly release water, thus preventing floods (Miller, 2002; Davies & Day, 1998; Barbier, 1993). Wetlands filter water and break down toxic wastes and organic debris. They also maintain stream flow in dry periods by slowly releasing water into streams (Miller, 2002; Davies & Day, 1998). Wetlands turn more carbon into living tissue than the rain forests do. They thus produce food and sequestrate carbon, and help maintain the nitrogen cycle (Faulkner, 2004; Davies & Day, 1998). Wetlands convert nitrates to nitrogen and break down human organic waste. They filter and trap sediments, nutrients, phosphorus, heavy metals and pathogenic bacteria. These settle as the water moves slowly through the wetland. Water leaving a wetland is cleaner than it was when it entered. (Faulkner, 2004; de Groot *et al*, 2002; Miller, 2002; Davies & Day, 1998). Disney World uses these ecosystem services in a restored wetland to process all the sewage they produce (Adolphson, 2004).

2.4.4.2 Habitat functions

Habitat functions include the refugium function, which is simply providing shelter and breeding space for organisms within the ecosystem, and nursery functions, where a species can breed and have the young develop in a relatively safe area while their adult lives will be spent elsewhere (de Groot *et al* 2002).

2.4.4.3 Production functions

Photosynthesis and nutrient uptake by producers are the source of food and also of many raw materials used by humans, e.g. lumber, paper, medicines, thatching and cut flowers (de Groot *et al,* 2002; Miller, 2002; van Wilgen, Cowling & Burgers, 1996). Change in land use leads to loss of ecosystem services, such as the provision of fodder for grazing. If land is not managed for grazing, unpalatable, tough grasses will tend to dominate over time, and thus the quality of grazing will deteriorate and will even affect the recycling of nutrients, as tough leaves do not break down as quickly (Quétier, Lavorel, Thuiller, & Davies, 2007).

2.4.4.4 Information functions and ornamental resources

The great diversity of living things and natural ecosystems provides a record of evolutionary pathways as well as providing recreation (de Groot *et al*, 2002). Wetlands provide recreation such as fishing and bird watching (Davies & Day, 1998). Ecotourism, which is "a responsible travel to natural areas that conserves the environment and improves the well being of the local people" (Sebola, 2008:60), brings in valuable foreign currency (Sebola, 2008; Miller, 2002).

Apart from the financial value of natural spaces, there is the effect that they have on human beings. Exposure to nature has been shown to enhance a person's ability to reflect on problems, it increases positive emotions, and restores an individual's ability to concentrate and pay attention (Mayer, Frantz, Bruehlman-Senecal & Dolliver, 2009).

Richard Louv (2005) coined the term "Nature Deficit Disorder" for the problems exhibited by modern children who have lost contact with the natural world and spend most of the day in front of a computer or the TV. He admits that safety issues hinder the child's access to natural areas, but feels that it is essential to find a way of letting children loose in a natural environment. His belief in the value of nature is supported by the finding that parents of children with attention deficit disorder (ADD) found that attention deficit symptoms were more manageable after the child had been out in green settings. Greener everyday environments were correlated with symptoms being generally more manageable. Most of the activities listed as reducing attention deficit symptoms took place in green settings (Taylor, Kuo & Sullivan, 2001). They suggest that children with ADD should spend time outdoors in a natural setting before engaging in demanding tasks. Just having a view of trees and grass out of the window of a university residence or an apartment block can help improve learners' and students' ability to focus attention (Taylor, Kuo & Sullivan, 2002; Tennessen & Cimprich, 1995). Public housing should incorporate trees and grass in spaces for children. Schools should consider including trees and grassy areas in the playground (Taylor, Kuo & Sullivan, 2002). From the above it is evident that humans depend on the environment far more than they realise, and alerting learners to the services provided by natural ecosystems would help to preserve those services.

2.5 Politics and ecology

Politics is about who manages society and how power and information are distributed (Webster, 2003). Politics invades every segment of human activities and particularly that of ecology because, as Peacock (2004) asserts, all decisions taken have some impact on the environment. If we are to change to a perspective that protects the earth we need to have the backing of politicians, otherwise nothing will get done, because these changes require major lifestyle changes which are strongly resisted by all, even the poor who hope to attain to a better life. Political leaders are afraid to tell their voters that they need to cut back on consumption (Oskamp, 2000) and, as he points out, national governments and multinational corporations are a law unto themselves.

It is ironic that most people in the Western World consider themselves to be democratic, and indeed their governments are democratically elected. Once elected these governments have little control over policies that are detrimental to the environment and to justice, because such policies are controlled by the World Trade Organization and multinational (transnational) corporations (Wilkinson, 2006; Oskamp, 2000; Cobb, 1995; Daly & Goodland, 1994). Hargreaves (2003) and Wilkinson (2006) use the term "McWorld" to describe a society that has very limited choice about things that are totally unimportant, and no choice about what is important.

The primary function of a corporation is to increase the wealth of owners of the corporation. The owners of the corporation are those who have shares of stock in the corporation (Freeman, 1994). Morality should direct the relationship between the managers and shareholders, but Freeman questions this. He draws attention to the fact that in most business and business ethics literature, business decisions are separated from moral decisions and thus, if it is a business decision, it has no moral content and if it is a moral decision, it has no business content. This he calls the "Separation Thesis" and maintains that it is commonly accepted at business schools, though maybe not under that name. According to the "Separation Thesis" we cannot make a moral judgement on business concepts up for scrutiny because they are not moral issues. We therefore need a business ethicist to look at each concept individually and determine its morality. Business theorists can then claim that business theories are morally neutral, a viewpoint not supported by Freeman (1994). As we shall see, what is good for business is not often good for the environment.

2.5.1 Using the business paradigm

After the oil crisis in 1973 sources of funding dried up and education became a problem. This led to education being linked to business (Hargreaves, 2003). When the business paradigm is used, everything must pay for itself, and this includes education (Ntshoe, 2003). How would one put a financial value on the contribution of a good teacher? How can education pay for itself if its true value is not recognised? Business has extended its influence to schools and, as Hodson (2003) says, corporate business is "re-engineering people in its own image" by training them in "consumership". Jurik (2004:1) warns:

> We now live in a society characterized by a hyper-privatization that is reconstructing everything from non-profits and government, to community, family, and individual life all in the image of the market.

Business organisations now claim total loyalty from their employees. Employees' private lives must be at the disposal of the corporation. They are expected to buy into the aims and mission of the corporation without questioning (Jurik, 2004; Gee, Hull & Lankshear, 1996). This leaves very little individual freedom.

We are in a global knowledge economy which puts pressure on education. This pressure has led to more standardisation of education, with the accompanying loss of creativity (Zhao, 2008; Wilkinson, 2006; Hargreaves, 2003).

Another effect on schools has been that they must find ways to supplement their funding from government, because the funding is no longer adequate. This has led to the situation where big business has stepped in and used the opportunity to get advertising into schools. Many South African schools have their name boards sponsored by firms like Coca Cola or McDonalds. Watts' (2004) research in Britain shows that teachers are aware of the dangers of this type of advertising access to children. They are more worried about it than are parents, which she interprets as showing the trust that parents have in teachers as gatekeepers. She indicates two areas of concern: direct aggressive marketing to children, and childhood obesity. It is up to the teachers and principals to protect children from direct aggressive marketing. Teachers found rewards for loyalty, by which schools received a proportion of the profits resulting from parents or children buying the company's products, acceptable, but parents tended to question them (Watts 2004). The question remains, can one teach about healthy eating when the school's funding comes from McDonalds or Coca Cola?

2.5.1.1 Origin of the Business Paradigm

The aftermath of World War II led to a move from concentrating on the importance of politics to thinking in terms of economics because of the need to rebuild economies. The International Monetary Fund and the World Bank were established at a meeting of the United Nations at Bretton Woods in 1944 (Calderisi, 2007; Cobb, 1995). The General Agreement on Trade and Tariffs (GATT) was signed in 1947 (Daly & Goodland, 1994). GATT aimed to break down all trade barriers and eliminate discriminatory trade policies (Cobb, 1995; Irwin, 1995). GATT was transformed into the World Trade Organisation (WTO) in January, 1995 (Irwin, 1995). Cobb (1995) notes that the United Nations was supposed to deal with international affairs and Bretton Woods institutions were to deal with the global economy, but in effect Bretton Woods institutions control both international affairs and the global economy. This creates much injustice and great pressure on the environment because poor countries are unable to raise tariffs in order to protect their own industries, but the North still has tariffs and trading restrictions (Osborn, 2003; Keller & Brummer, 2002; Cobb, 1995; Brundtland, 1987).

2.5.1.2 Effects of the Business Paradigm

This state of affairs is to the advantage of the rich countries, and current economic policies concentrate wealth in the hands of a few, transfer wealth from poorer countries to richer countries, and speed up the destruction of natural resources (Adolphson, 2004; Chapman & Pearce, 2001; Cobb, 1995; Corson, 1995; Daly & Goodland, 1994). We therefore require a new economic system (Adolphson, 2004; Odum & Odum, 2000). When the business paradigm is adopted efficiency of production becomes of prime importance. Each nation sells its labour and goods as dearly as possible, and gets labour and goods from other nations as cheaply as possible. According to this theory government intervention in the market should be minimal. An increase in market share means more specialisation, which leads to economies of scale and thus increased efficiency, decreasing prices and increasing consumption. It is hoped that the world market will allow nations to specialise more. Anything that decreases efficiency is regarded as an obstacle to growth, thus laws that protect the environment and thereby increase the cost of production are considered bad (Cobb, 1995; Daly & Goodland, 1994). One of the many problems with this system is that trade is not mutually beneficial, as both parties do not understand the value of what they are trading and there is thus a built-in bias against the less-developed trading partner, because the less-developed partner depends more heavily on nature, and those costs are not included (Adolphson, 2004).

What happens is that rich industrial nations have laws to protect the environment, so business simply moves to a poorer country that does not have such laws. In richer countries the effect of the withdrawal of a large corporation is negligible compared to the withdrawal of a large corporation from a poorer country, thus richer countries are able to protect their environments without regard to the corporations. When business is governed by competition, decisions made are not guided by environmental concerns (Cobb, 1995). Producing cheaply and getting rid of waste cheaply are most important. This leads to disposal of waste in rivers which causes fish to die, thus decreasing the income of fishermen. Advanced industrial nations have rules for disposing of waste (Cobb, 1995). Such things are called "externalities". These should be internalised, but since some producers do not take these externalities into account when pricing their goods, others cannot afford to include externalities in their pricing (Keller & Brummer, 2002; Miller, 2002; Oskamp, 2000; Cobb, 1995; Daly & Goodland, 1994; Quarrie, 1992; Brundtland, 1987). Economists cannot see the need for internalisation.

Odum & Odum (2000) turn economists' reasoning upside-down with their claim that it is time to "externalize the internalities" and put the economy and the work done by ecosystems on the same footing, so that the work of the ecosystem can be fully appreciated. To do this they suggest that the uses of energy should be compared. The term "emergy" is used to express the valuations in one kind of energy, so that all goods and services can be compared in the same terms. Emdollars is the economic equivalent of "emergy" and is defined "as the GNP equivalent to 'emergy' contributions." Evaluating ecological data in this way enables ecologists to influence environmental policies (Odum & Odum, 2000:22).

Companies in countries with low environmental standards have the advantage over those in stricter countries. An example used by Cobb (1995) is how American companies moved to Mexico in the 1980s because they did not have to pay to clean up and could dump their waste in the Rio Grande. Now the Mexican tax payers have to pay the cost of the cleanup. The Bush administration paid little attention to environmental issues. States that wanted to enact stricter legislation were told that more businesses would move to Mexico if they did so. This meant that slowing environmental decay was difficult (Cobb, 1995).

Another consequence of "free trade" suggested by Daly and Goodland (1994:397) is that "labourers may have their wages competed down to third world levels." They advocate a reduction of "economic entanglement" between countries. Prices for agricultural produce can be pushed down by overproduction in Western countries as a result of free trade (Keller & Brummer, 2002).

The goal of a free market system is to increase the Gross Domestic Product (GDP), which it is claimed will cause a trickle-down effect and increase the standard of living of the poor (Brundtland, 1987). Unfortunately this does not happen. The dangers that these policies pose to society and the environment have been documented by many (Hodson, 2003; Miller, 2002; Oskamp, 2000; Cobb, 1995; Corson, 1995; Quarrie, 1992). The breakdown of communities that has resulted from these policies has led to moral decay in some societies. Modern agribusiness has deprived many farm labourers of their jobs, and has led to slums surrounding cities as these people seek work in cities (Cobb, 1995).

Traditional values cannot be maintained in the slums, therefore there is an increase in crime, drug use, and violence. This has happened alongside a growth in GDP, i.e. the achievement of the goals of free market policies (Cobb, 1995). So, is the goal worth achieving if those are the results? The answer to this is usually that more growth is needed to integrate these people into the system, as suggested by the Brundtland Report (Brundtland, 1987), but this has not happened in the twenty-four years since the Brundtland Report appeared. In fact, poverty and environmental destruction are increasing (Osborn, 2003; Thérien, 1999; Gee *et al*, 1996; Cobb, 1995).

However, Raudsepp-Hearne *et al*, (2010) maintain that human well-being is increasing despite the degrading of ecosystem services. They use the following five components to define human well-being: basic materials, health, security, good social relations and freedom of choice and actions, and rely on the human development index (HDI), which includes life expectancy, literacy, educational attainment, and per capita GDP, to give an indication of human well-being.

Cobb (1995) suggests the use of The Index of Sustainable Economic Welfare (ISEW), which gives a better indication of actual welfare. It starts with personal consumption and adjusts this in relation to income distribution. Contributions made by housewives are recognised, and the costs incurred because of economic growth are subtracted (e.g. commuting to work, which definitely does not add to well being). The costs of pollution are also considered and, unlike GDP which just considers economic welfare, the ISEW includes social issues (Cobb, 1995).

Postmodernists argue that science is no different from any other human activity. They suggest it is not objective. This has led to the "science wars" (Grinnell, 2000). It is fashionable to vilify "Western science", as Bencze (2000) does when he complains that school science focuses exclusively on Western science and excludes all other ways of knowing. He suggests that this is to the benefit of transnational corporations. This perception is a direct consequence of the use of the business paradigm.

Because scientific research is expensive to conduct and because every activity must pay for itself, scientists now have to compete for funding since governments do not provide adequate funding for research (Cobbing, 2011; Laudel, 2006; von Gruenewaldt, 2001). When scientists accept funding from transnational corporations, they are at risk of losing integrity because their research findings must satisfy their funders. Scientists working in multinational corporations run the risk of losing their jobs if their research findings are not what the corporation wanted (Webster, 2003). Hirschhorn, Bialous & Shatenstein (2001:247) discuss the Philip Morris Tobacco Company's External Research Program, which aims to "provide scientific evidence to encourage accommodation of smokers' right to smoke", to re-establish Philip Morris' credibility, and to provide a "balanced view" of smoking and health. This is clearly business subverting science, and it is business that is the villain, not science, as Hodson (2003:649) warns:

> The merger of science and technology into technoscience, the appropriation of the knowledge-making capacity of science to promote the interests of the rich and powerful, and the usurping of the scientific and technological endeavour for the goal of ever-increasing levels of material consumption, have profoundly changed the socio-political and moral-ethical contexts of scientific and technological practice.

While denigrating "Western science" people still want what it can offer, such as cars and cell phones (Mooney, 2009; von Gruenewaldt, 2001). The fact that science is a human activity does not make it ridiculous or worthless. Science has given us invaluable insights and very useful technologies. We need to find out how to use what science offers for the benefit of society, not merely to serve some ideology (Mooney, 2009).

2.5.1.3 Maintenance of the business paradigm

In order to maintain the inequalities that are produced by the business paradigm some form of control is needed. This control is exercised by the media, owned by large corporations, through propaganda (Hodson, 2003; Corson, 1995; Chomsky, 1989). The media fuels the drive for greater consumption of goods (Oskamp, 2000).

When anything harmful to business interests is suggested, the media will divert attention in various ways. One way of doing so is the so-called "balanced reporting", which insists that an opposing voice be found and reported on. What this leads to is a distortion favouring views that are held by very few. An example of this is the Global Warming debate. Scientists are in agreement that global warming is increasing as a result of human activities (Boykoff & Boykoff, 2004; Ball, 1999). This view threatens the oil conglomerates and industry, so newspapers engage in "balanced reporting". Balanced reporting has amplified the views of a small group of sceptics by giving them the same amount of time as the much larger group. In the case of global warming, they "obscure the big picture." Such reporting gives equal attention to the large group of scientists who agree and to the small group of dissidents (Boykoff & Boykoff, 2004).

Another tactic is to cast doubt on scientific findings. The fossil fuel lobby conducted a disinformation campaign on the issue of global warming. The Intergovernmental Panel on Climate Change (IPCC) scientists are in agreement about anthropogenic causes of global warming, but the public is presented with the picture of uncertainty

(Monbiot, 2007; Dispensa & Brulle, 2003). The political "left" claimed that science was just another way of knowing and that it offered no more than other forms of knowing, and the political "right", the Bush administration, distorted, suppressed and denied evidence given by scientists (Mooney, 2009).

An additional way of controlling people is to get them into debt. As Watkins (2000:909) points out, advertising creates desires to try to be like others, and credit enables those desires to be fulfilled.

> In exchange, corporations receive a claim to the future income of consumers, a claim that disciplines the worker, molding his time, habits, and ideas to the corporation's pursuit of pecuniary values.

This fits in with Frank's (2005) belief that the traditional economic theories that claim that individuals spending on themselves promote the welfare of all are inaccurate, because people will spend to maintain their social position. This reduces the social position of those below them, who will then spend more to regain position with reference to others. He notes that those who persuade governments to cut taxes for the wealthy are in effect reducing spending on more important things like welfare and education. People become ensnared in the cycle to the benefit of corporations and no one else (Frank, 2005; Watkins, 2000).

2.5.2 Decision-making

Corporations and governments take decisions based on economics, and rarely consider the environmental impact of their decisions. Hattingh (2004) discusses three models of decision-making. In the first model there is a dominant theme suggesting that social-political, economic and environmental spheres be linked together for sustainable development, as in a Venn diagram of three overlapping spheres. The spheres of technology and governance have been left out.

Another model is of three pillars supported on the foundation of technology and governance. When probing what integration of these spheres means, two common answers are "finding the right balance" between them, or "finding optimal trade-off". Such models imply that each sphere or pillar can work according to its own rules to achieve its own goals with its own logic and values. The three-pillars model gives no indication of how the pillars impact on one another, or of how they interact with one another. Usually the costs in the environmental sphere are offset by benefits in social and economic spheres. This model ties us to thinking in terms of moderating the costs borne by society and the environment because of economic activity and human development. It would have us believe that resources can be substituted for each other, so that it is unimportant if one resource becomes depleted since another one will serve just as well (Hattingh, 2004). This attitude is at the root of all our current problems.

The three-pillars model does not consider the intrinsic value of nature. Doing a cost-benefit analysis and choosing how to act on the basis of that analysis is not always as rational as economists would have us believe (Jamieson, 1992). He notes that every day we see choices made on entirely different grounds, like altruism, or love of our partners. When we know so little it is impossible to honestly believe that an economic analysis can be done, and that if it is done it can yield enough information to determine the best course of action (Jamieson, 1992). Cost benefit analyses usually leave out the benefits provided by the ecosystem (Bolund & Hunhammar, 1999), and are thus biased against the ecosystem.

There is a third model that Hattingh (2004) discusses that would more accurately reflect the world in which we live. It represents political, economic and environmental spheres as three spheres embedded within each other and inseparably intertwined. All social life impacts on the environment and lies wholly within the environmental sphere, while all economic activity lies wholly within the social sphere (Adolphson, 2004; Hattingh, 2004).

This model causes us to speak of precautions and minimum standards, and non-negotiable thresholds. Adolphson (2004) refers to this model as the biophysical model and contrasts its principles with those of business. In business, the dominant principle is the "maximum profit principle." Adolphson (2004:206) quotes Friedman's definition of this principle as:

> There is one and only one social responsibility of business - to use its resources and engage in activities designed to increase profits so long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud.

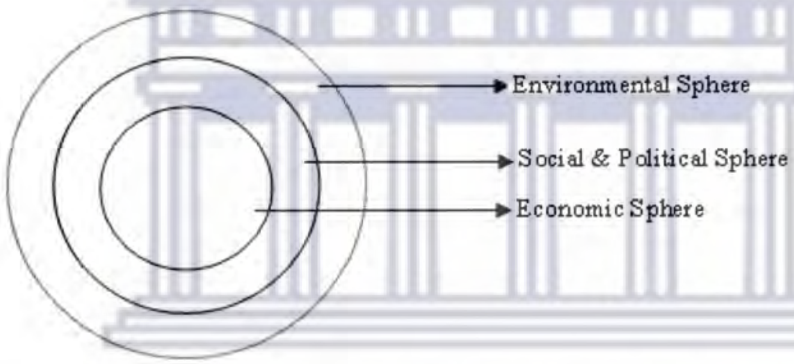

Figure 1: The Biophysical Model of Decision-making

This principle answers to investors and is supposed to result in the "best overall allocation of resources with the larger community", which is patently not so since even Brundtland (1987) acknowledges that economics favours the rich. In the biophysical model the "basic maximum power principle" is used which states that:

> Natural systems adapt in a way that captures and uses all sources of energy as effectively as possible (Adolphson, 2004:206).

If the third model were used in decision-making in corporations there would be much less environmental damage but, as Di Castri (2000) notes, decisions about development are shaped by the global economy and an information society, because ecologists do not provide any practical information that can be used by economists.

They cannot even agree about placing a monetary value on ecosystem services. Di Castri (2000;322) warns:

> Applicability of research results is not only a scientific concern to be addressed by scientists alone. It has mainly to do with economic and political policies, with social attitudes, and with cultural perceptions.

Mad cow disease was the result of feeding practices that came about because of cost-cutting in order to increase profit margins. From the biophysical approach the risks of harm to consumers and cattle would have outweighed the profits (Adolphson, 2004).

"Sustainable development" was proposed to reconcile the environment and economics (Di Castri, 2000). Agenda 21 holds that sustainable development requires sound economic policies, efficient public services which integrate environmental concerns into decision-making, and a democratic government (Quarrie, 1992). There are questions as to whether sustainability is possible.

2.6 What is "Sustainable Development"?

The amount of controversy generated by this term makes a concise definition extremely difficult. There are over eighty definitions for sustainable development, and it is thus a "dangerously vague" term (Mebratu, 1998). Mebratu goes on to point out that it cannot guide development since there is no operational definition that shows how it can be applied. This leads to a situation where whoever can impose their definition of the term on the rest of the world will gain a lot of political influence in future.

The Brundtland Report (Brundtland, 1987:40) defines it as:

> Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future.

This definition includes the concepts of "needs", "aspirations", and the "limitation of the ability of the environment to meet those needs" (Beckerman, 2007). How would it be possible to meet the "aspirations" of a future generation? A synonym for "aspiration" given by the Concise Oxford Dictionary is "an ambition" which would be difficult to provide for in current circumstances, let alone for a future generation. It is inherent in the structure of society that the ambitions of the strongest/wealthiest would be met while those of the weakest/poorest would be ignored.

Beckerman (2007) points out that the concept of "needs" is subjective. The importance of different "needs" differs with time and circumstances, so what is important today may not be a "need" later. The Brundtland Report notes that the process of sustainable development involves an interaction between technological development and the use of resources so that the levels of available resources are taken into account and not over-used, or, as Bybee (1991:148) puts it:

> Sustainable growth refers to patterns of development that maintain a long-term balance between population demands and environmental capacities.

Miller (2002) has two interlocking definitions of sustainable development: ecologically sustainable development and sustainable economic development. Both of these definitions include the necessity of not depleting natural resources.

2.6.1 Barriers to change towards Sustainable Development

Agenda 21 is an agenda for Sustainable Development adopted by world leaders at the Rio Earth Summit, but there has not been much progress towards achieving its goals (Osborn, 2003; Pillay, Rosswall & Glaser, 2002). Progress has been blocked by big business, oil and mining companies, and cigarette and drug companies that back attacks on environmental protective legislation (Monbiot, 2007; Oskamp, 2000). The main sources of the problems are overpopulation, over-consumption and under-conservation (Oskamp, 2000). Corson (1995) lists the following barriers to change:

- the belief that Earth's natural systems cannot be harmed by human activity;
- lack of convincing evidence that current practices are unsustainable;
- excessive and conflicting information;

- refusal to accept personal responsibility;
- belief that action costs too much and benefits are too small;
- belief that resources for change are unavailable;
- belief "that action to counter threats would be incompatible with one's values and beliefs";
- lack of social support for change;
- lack of institutional will to change harmful policies;
- vested interests.

2.6.2 Is Sustainable Development possible?

As long as the gap between the rich and the poor continues to grow there is no chance of sustainable development. Why should the poor be expected to be content with what they have and not strive for the level of consumption enjoyed by the rich? As Cobb (1995: 91) points out, the

> forces that now rule the world will not accept any form of development for the poor that does not increase their own wealth and power.

This means that the gap would still be the same as ever, and Maume's (2004) study showed that the racial and gender wage gaps have actually increased over time.

Bringing the rest of the world to the level of consumption of Canada and the USA would require three planet earths (Miller, 2002; Oskamp, 2000). Faulkner (2004) says it would require four planet earths, and Rees (1997:72) notes:

> First, it is clear that without massive increases in material and energy efficiency, the present material standards of high income urbanized countries cannot be extended sustainably to even the present world population. There is simply not sufficient natural capital to go around.

When individuals break the poverty cycle, the first thing they do is change their diets to more heavily meat-based diets, which stress the environment since the animals are fed grain. The next thing they do is to buy a car (Myers & Kent, 2002). "Raising 1 kg of beef can use 8 kg of grain, 4 kg of pork, and 2 kg of poultry (Myers & Kent, 2002:4964)." The growing grain requires water, so the country's water supplies are put under pressure, and the increase in the number of cars increases the CO_2 emissions.

Odum (1992) suggests "A parasite-host model for man and the biosphere is a basis for turning from exploiting the earth to taking care of it", and Rees (1997) confirms this, saying that we are in a state of "obligate dependence" on the ecosphere. The values and actions we have now are human values. Decisions taken were taken by humans. The knowledge we have was developed by humans and the problems caused were caused by humans and thus have a human solution that must be found. (Hodson, 2003; Mortenson, 2000; Oskamp, 2000; Jamieson, 1992). Because of this Jamieson (1992) believes that education can help to change values.

2.7 Problems facing South African schools

In the first chapter of his book, "The Toxic Mix", Graeme Bloch (2009) states plainly that 60 – 80% of schools in South Africa are dysfunctional. The reasons for this are complex and, as he points out, laying blame will not help solve the problems. This section will look at the problems with society as they relate to schooling, the school, school support (Department of Education and parents), teachers and classroom, learners, parents and home. These problems are all interlinked, so it is acknowledged that this way of discussing the problems might give a simplified picture.

2.7.1 Society and the environment around the school

Schools tend to reflect the society in which they find themselves (Bloch, 2009; Phurutse, 2005; Hargreaves, 2003). Because there are differences in the socio-economic status of various communities in South Africa, it is clear that the society surrounding a school will affect that school, and that the effects will relate to the type of community around the school. In South Africa we have wealthy former Model C schools situated in safe, middle-class neighbourhoods, but they are not the norm. We also have schools surrounded by sub-economic housing or informal settlements.

Giving an "average" picture of society would hide the tremendous effort that some people must make to get an education, and to look neat and clean every day.

Statistics South Africa (StatsSA) (2007) gives a summary picture of South African society. In 2007 only 28% of the population had completed secondary school and 10.3% had no schooling at all. Twenty percent did not have electricity for lighting. Eleven point four percent did not have water piped to their homes. Thirty-eight point five percent did not have either flush toilets or dry toilets in their homes. Fifteen point seven percent had computers at home but only 7.3% had access to the Internet. These statistics, though not current, do give an idea of the problems facing many South African households.

The environment around the school is often unsafe (Maarman, 2009), with violence occurring in the area and often even on the school grounds (du Plooy, 2010; Pretorius, 2007; Zulu, Urbani, van der Merwe, & van der Walt, 2004)). Teaching in poor communities is hampered by a lack of community structures, vandalism, negative peer pressure, substance abuse, an environment lacking in stimulation, a negative attitude to school, and a conflict between the values propagated by the school and those of the home. Other problems are unplanned urbanisation, depopulation of the rural areas, serious deterioration of norms and values and the concomitant moral decay and increase in crime and violence. The AIDS epidemic and globalisation are also problems for the Department of Education (Pillay, 2004; Prinsloo, 2004; Zulu *et al* 2004).

Unemployment is high in many areas. In Zulu *et al's* (2004) study, 60% of the respondents said that their parents or guardians were unemployed. In some rural areas even R40 per pupil per year was too much for some parents to be able to afford (Phurutse, 2005). Unemployment creates stress, competition for scarce resources, and a certain feeling of hopelessness which can lead to violence (Phurutse, 2005; Prinsloo, 2004; Zulu *et al*, 2004). Unemployment means that food can be scarce and often learners go to school hungry. Malnutrition is rife among the children whose parents are unemployed (Bloch, 2009; Pretorius & Mampuru, 2007; Pillay, 2004; Khoza, 2002).

Gangs are more attractive to learners than school because gang members have material goods that children want. Gangs also provide protection for their members and a sense of belonging (Bloch, 2009).

2.7.2 The school

Unfortunately, after 17 years of democracy the inequalities in schools have not yet been eradicated. Bloch (2009) claims that education so far has reinforced the inequalities in society. He does however warn that even the complacent Model C schools are underperforming, when compared with the rest of the world or even the rest of Africa.

Incidents of violence on playgrounds where learners end up in hospital are often ignored (Pretorius, 2007; Poggenpoel & Myburgh, 2002). In one study 75% of the learners felt that school is not a safe place (Zulu *et al,* 2004). The Zapiro cartoon below gives a good idea of problems (Shapiro, 2007:13).

Figure 2: Violence at Schools

Conditions in schools are such that teachers are becoming discouraged and leaving for jobs that offer better pay and better working conditions (Xaba, 2003).

2.7.2.1 Infrastructure and facilities

As indicated above, one cannot give a description of a "typical" school, but Bloch (2009) gives figures which might lead one to conclude that a poor public school might be fairly typical. According to him only 10% of learners are in ex-model C schools and 3-5% in independent schools. Former Model C schools are well-equipped and have buildings that are well cared for (Mncube, 2009). Decaying, neglected buildings with faulty electrical wiring and damaged furniture, a shortage of essentials such as running water, toilets, electricity, windows, textbooks, laboratories, libraries, and desks, often characterise the poorer schools. What doors and windows there are, are broken. The walls are covered with graffiti and waste is strewn around. School grounds consist of bare earth with patches of uncut grass (Bloch, 2009;

Kamper & Mampuru, 2007; Pretorius & Mampuru, 2007; Phurutse, 2005; Zulu *et al* 2004; Khoza, 2002). Bloch (2009) describes teachers having to use buckets in toilets without doors, while learners in rural areas have to use pit latrines.

Only 27% of schools in South Africa have libraries, so most children live in a print-poor environment, which makes learning to read difficult (Pretorius & Mampuru, 2007). de Vries & van der Merwe, (2004) put it at 17% in 1996. They note how difficult it is for schools to use the budget given for library books when there are so many other problems.

2.7.2.2 School governance

In 1997 School Governing Bodies (SGB) started functioning. They consist of the school principal, representatives of parents, learners, teachers, non-teaching staff, and the community. They are tasked with creating an environment that fosters teaching and learning, upholding the interests of the school, ensuring a safe environment for learners, deciding on uniform policy, disciplinary policy, and determination of school fees. They decide on and endorse a code of conduct for learners and teachers, and endorse curriculum programme development (SA Schools Act, Act 84 of 1996). The communication between home and school should be a two-way communication in a "co-equal" partnership (Mncube, 2009), but since many black parents are not well-educated and spend long hours travelling, this ideal is not always met (Maarman, 2009). In former Model C schools, black parents who are on the SGB have trouble attending meetings because they have to get permission from their employers to attend SGB meetings during the day, and employers do not want to give that permission (Mncube, 2009).

Often the School Management Team usurps the position of the SGB, and while parents may resent this they feel powerless to complain because they are afraid of 'academic victimization' (Mncube, 2009). The fact that in former Model C schools all interactions take place in English can be intimidating to black parents who are not fluent in English (Mncube, 2009). This is probably also true for others whose second language is English.

The circumstances in which poor schools find themselves are such that it is very difficult to do anything to change the situation, and though in theory School Governing Bodies should be democratically chosen and should have a say in improving the school, in actual fact they have only "abstract freedoms" because they cannot do much to improve the situation (Maarman, 2009). Many parents are not well-educated and do not feel able to participate in the SGB activities, but despite this they do try to participate (Mncube, 2009).

2.7.2.3 The curriculum

Egan (1997:9) sums up what school is for many learners:

> School – that business of sitting at a desk among thirty or so others, being talked at, mostly boringly, and doing exercises, tests, and worksheets, mostly boring, for years and years and years – is the instrument designed to deliver expensive benefits.

Another view of education is Pollak's (1993:517)

> Education is the means whereby knowledge acquired by earlier generations through experience is transmitted to the present generation through belief.

This demonstrates that we do not expect learners to make knowledge their own or to take an active part in their own learning. While South Africa is supposed to have Outcomes-based Education, which makes lessons relevant to the world in which the learners live (Le Grange & Reddy, 2000), in practice learners see little connection between what they are learning and the world they live in (Bloch, 2009; Plonczak, 2008; Le Roux, 2001; Battersby, 1999). How they learn, what they learn and when they learn it is decided for them by their teachers and the curriculum. They seldom, if ever, deal with real situations. Learners can carry out learning activities without necessarily being involved in learning (Battersby, 1999; Uzzell, 1999).

Education has tried unsuccessfully to change the attitudes of children towards the environment. They are given lots of facts and environmental problems are discussed at length but there is no noticeable change in their orientation toward the environment. (Uzzell, 1999) In fact, all it has done is cause "action paralysis" (Jensen, 2004).

2.7.3 School support

School support comes mainly from the Department of Education and the parents. Parental support will be discussed later.

2.7.3.1 The Department of Education

The National Education Department provides the funding for provincial education departments to resource schools and, as Bloch (2009:110) points out:

> Once the budgets are transferred to the provincial treasury and are subject to provincial shaping and design, the national education department cannot even insist that monies allocated from the national treasury for education are actually spent on schooling rather than, say, welfare shortfalls.

This arrangement puts another layer of politicians between what is intended by the national department and the implementation of those intentions, and also opens the way for more corruption (Bloch, 2009).

There is thus a significant difference between provinces relating to what they spend on education. Schools supplement their budgets with school fees. The wealthy provinces, Western Cape, Gauteng and Northern Cape, tend to have higher school fees, on average R800 per annum, while Eastern Cape, Mpumalanga and KwaZulu-Natal have average school fees that are under R100 per annum (Phurutse, 2005). He notes that some urban schools charge up to R5 000 per annum. Setting school fees that high means that these schools are not accessible to poorer children, though the policy of not allowing schools to turn away learners who cannot pay school fees can neutralise this effect. The counter to this policy is that schools are obliged to take learners from their communities, so such schools simply say they do not have space for learners who do not pay fees, and wealthy schools continue to serve the wealthy (Phurutse, 2005).

District-level departmental structures should provide support for schools, but they have made things more difficult for teachers by requiring extra paperwork and finding ways to exert their authority over teachers (Bloch, 2009).

2.7.4 Teachers and classrooms

2.7.4.1 Class size

Seventy percent of teachers in Limpopo Province taught classes of 46 and some up to 65 learners in a class, while in the Western Cape there were 35 in a class in many schools (Phurutse, 2005). Black teachers tend to have more learners in their classes. This may be because there are more black teachers in the rural areas where the classes are larger, and there is greater poverty and a higher incidence of HIV/AIDS (Phurutse, 2005). Over-crowding makes it difficult to maintain discipline (Mokhele, 2008). To realise how crowded our classrooms are we need to note that "large classes" in America refers to classes of 22 – 26 (Nye, Hedges, & Konstantopoulos, 1999).

2.7.4.2 Work-load

Black teachers also tend to have a heavier teaching load with more hours of teaching than white teachers (Phurutse, 2005), but Chisholm, Hoadley, wa Kivulu, Brookes, Prinsloo, Kgobe, Mosia, Narsee, & Rule, (2005) note that black teachers tend to spend less time actually teaching their classes. They studied ten teachers at ten different schools. They recorded the teachers' activities at 5-minute intervals throughout the formal school day for three days (Monday, Tuesday and Friday). The time spent on actual teaching ranged from 6% to 56% of the time allocated for teaching. They found that School F lost 90% of teaching time to other activities and School A only 2%. Activities which took teaching time included, among others: sports training in the morning; practising for the choir competition; organising school portfolios; interruptions from outside (one teacher was interrupted 74 times in the three days of observation); organising for fundraising activities (one teacher made fudge and sold it at school). The class periods were simply shortened to accommodate sports training and choir practice (Chisholm *et al,* 2005). The shortening of class periods to accommodate other activities has been noted by others (Raitt, 2004).

There is a high turnover rate, which results in there being many teachers who are beginners (Kamper & Mampuru, 2007; Xaba, 2003). Teachers who stay have low self-esteem and lack initiative, and tend to use "drill and kill teaching". Unfortunately there are incidents where they show a lack of respect for parents and learners and are not loyal to their schools (Kamper & Mampuru, 2007). Respect for learners, parents and colleagues is one of the foundations for running a successful large school (Sailors, Hoffman, & Matthee, 2007; Allen, 2002; Darling-Hammond, Ancess & Ort, 2002).

Teachers' workload is a factor causing much unhappiness. Classes are larger than before, and teachers feel the new roles expected of them with the OBE curriculum are very demanding. The amount of record-keeping and administration has increased so much that little time is left for actual teaching (Chisholm *et al,* 2005). Classrooms are overcrowded (Pretorius & Mampuru, 2007).

Classroom interactions are often characterised by destructive interpersonal relationships, child abuse and neglect, physical violence, and prejudice. Confrontational, disruptive and destructive behaviour in general occurs in classrooms (Chadwick, 2004). Sixty-seven percent of children in the study reported that their teachers use corporal punishment (Zulu *et al*, 2004). Teachers themselves are sometimes rude to learners, which makes learners angry and resentful (Mokhele, 2008). Children and particularly adolescents, need to feel that they can trust the adults who teach them (Wasley, 2002).

Well-planned lessons make it easier to maintain discipline in the classroom, but many teachers do not plan their work well (Pillay & Sanders, 2002). If teachers wait for misbehaviour to happen before acting, discipline becomes difficult. They should plan to avoid situations where misbehaviour is likely to occur (Mokhele, 2008).

2.7.4.3 Relationships with learners

Bloch (2009:104) quotes a letter from a teacher who has taught at the same school for 22 years. The teacher talks of the frustrations of good teachers, who are expected to be "policemen, sexologists, criminologists, psychologists, drug counsellors, doctors, nurses, sports coaches, tour guides, peace-makers, pastors, fundraisers for the state" and teachers. He is frustrated by the bad name teachers have, and asks that the public refrain from generalisations. There are probably more good, dedicated teachers than there are lazy teachers who don't care. Unfortunately, some teachers are little more than criminals.

Some teachers do abuse learners. It is not the norm but it does happen in many schools. Khoza (2002) opens the article with a quotation describing how boys and some educators touch girls' breasts and private parts. There is also a quote from an educator who justifies sleeping with schoolgirls by pointing out that there is no form of entertainment available to teachers in rural areas. The fact that parents, educators and learners are perpetrators makes it more difficult to eradicate the problem. Perpetrators don't acknowledge that gender-based violence is a problem. It is often regarded as part of socialisation. Even women educators don't want to admit that violence occurs in schools (Khoza, 2002).

If learners are to accept the teachers' authority and discipline, then teachers themselves must model self-discipline. They should be in class on time. Their relationships with learners should be respectful to learners and maintaining their own dignity. Teachers should never insult or shout at learners (Mokhele, 2008). He found that teachers who allowed learners a say in classroom rules did not have difficulty maintaining discipline in their classes, because the learners had accepted the teachers' right to discipline. There were many teachers who had positive relations with the learners they taught (Bloch, 2009; Mokhele, 2008).

2.7.5 Learners

We tend to have a stereotypical view of poor children as aggressive, loud and troublesome, but the majority are quiet and have "quiet" problems (Weissbourd, 2009). These quiet problems are not easily picked up by teachers. They include a range of problems from hunger, dehydration, asthma, hearing problems and obesity, to depression, anxiety, loneliness, tiredness, low self-esteem, and fear of utter destitution. Not having a quiet place to read or to sleep can be a tremendous problem (Maarman, 2009; Weissbourd, 2009; Kamper & Mampuru, 2007; Olivier, 2006). Learners do not have tables on which to do homework. They share clothes with their siblings and have no private space. When it rains the roof leaks. It is difficult to get clothing washed. For some learners the safety and cleanliness of their home is more important than it is for others (Maarman, 2009; Pillay, 2004). Imagine getting up at 4:30 on a winter's morning to go and get water and firewood, and then making the fire and heating the water so that you can bath before walking to school. Imagine the shame and embarrassment when, after all that effort, your classmates tell you that you stink (Pillay, 2004).

Because of malnutrition, the accompanying lowering of immunity, and lack of money to get health problems seen to, many poor learners have health problems. Crowded conditions make the spread of infectious diseases easier. Parasitic infections, particularly intestinal worms (Bloch, 2009), are difficult to eradicate and easy to spread in conditions where keeping clean is a Herculean task. Foetal alcohol syndrome occurs extensively in the Western Cape (Bloch, 2009). Problems with eyesight and hearing are often missed by teachers and result in learning problems (Weissbourd, 2009).

Poor learners are often absent from school. Many learners have to look after sick parents (Weissbourd, 2009; Olivier, 2006), particularly in areas with a high incidence of HIV/AIDS (Bloch, 2009; Prinsloo, 2004). Learners from poor families often attempt to contribute to the family income, and will go out and work even though they are underage. This means that they miss school when there is work available (Prinsloo, 2004). Because parents work such long hours, children are left to do the housework, and many of them do not have time to do homework because they are busy with chores (Maarman, 2009; Pillay, 2004; Prinsloo, 2004). There is no time to discuss schoolwork with parents, and the environment is language-poor (Maarman, 2009).

Most learners in South Africa are taught in a language that is not their home language (Bloch, 2009; Pretorius & Mampuru, 2007; Xaba, 2003). Using language properly at home and simply discussing the happenings of the day are luxuries that most poor children do not experience (Maarman, 2009). Even learning to read in South Africa is difficult, because most children grow up in "print-poor" environments where reading for pleasure is unheard of. These learners do not have the chance to read a newspaper (Kamper & Mampuru, 2007; Pretorius & Mampuru, 2007). Thus most learners are at a disadvantage, because having a language-rich environment is the strongest predictor of school success (Weissbourd, 2009). Even where public libraries are available, disadvantaged learners do not benefit from them as much as middle-class learners, because poor learners seldom have an adult with them to help interpret what they read and to steer them in the direction of books that will build their knowledge (Celano & Neuman, 2008).

Travelling to school takes up a lot of learners' time. According to the StatsSA (2001), 34% of learners have to travel from 1 to 5 kilometres, and nine percent travel more than 11 kilometres to get to school. About 73% of them have to walk those distances in all weathers. There have been reports in the newspapers of children drowning on the way to school because of having to cross flooding streams (Maphumulo, 2006), so simply getting to school is an enormous problem (Kamper & Mampuru, 2007).

2.7.6 Parents and homes

For those parents lucky enough to have a job it often means leaving early in the morning to travel a long distance to work and then getting back late at night, so there is no time for 'quality' time with children and no time to help with homework, though often the parents would be unable do so even if there were time because they are not literate (Kamper & Mampuru, 2007). Parents have no control over their working hours and employment conditions, and even if they wanted to support the school they could not (Maarman, 2009). Often parents have had bad experiences at school themselves and have a deep distrust of school (Kamper & Mampuru, 2007). Parents who can afford it take their children out of township schools and send them to former Model C schools. This means that township schools get poorer and rich schools get richer (Msila, 2005). Many parents still use corporal punishment and cannot understand why teachers do not use it (Mokhele, 2008).

The eradication of poverty and living sustainably go hand in hand, and require a commitment to an education that addresses issues of importance to learners. The type of education envisaged in Learning Outcome 3 would fit this requirement, as will be seen in Chapter 3. Education is important, and the aim of education is to produce a literate population. This chapter has attempted to contextualise the schooling issues in South African schools as well as societal issues that impact on schooling. The conceptual framework the thesis draws on is constituted by scientific literacy, bioliteracy and eco-literacy. This will be presented in Chapter 3.

CHAPTER 3: SCIENTIFIC, BIOLITERACY AND ECO-LITERACY

3.1 Introduction

Scientific literacy encompasses both bioliteracy and eco-literacy. This chapter explains the importance of scientific, bioliteracy and eco-literacy, which form the conceptual framework for this study. How the Learning Outcomes of the National Curriculum Statements for Life Science and Natural Sciences encourage the development of bioliteracy is then explained. The chapter goes on to show how Learning Outcome 3 (DoE, 2003; DoE, 2007) could have been used to produce scientifically and biologically literate learners.

3.2 What is Scientific Literacy?

What is scientific literacy? Bioliteracy, which is a form of scientific literacy, is the ability to apply scientific knowledge to personal and social phenomena (Klymkowsky, Garvin-Doxas, & Zeilik, 2003). Scientific literacy exists on a continuum and across many fields – even scientists are not necessarily literate in a totally different field of science (Osborne, 2002; Uno & Bybee, 1994; Shamos, 1988).

Peacock (2004:2) gives the following diagram to show what eco-literacy means.

ECOLOGY — How we relate to our Environment
↓
How we depend on it

ECONOMY — How we manage our Environment
↓
How we influence it

How we depend on it ______________ How we influence it
↓
ECO-LITERACY
Knowing about the consequences of our actions (and inactions)

Figure 3: Links between Ecology, Economy and Eco-literacy.

Table 3.1 below gives an overview of five conceptions of the degrees of literacy, including literacy in terms of being able to read as well as scientific and biological literacy.

Table 3.1 A comparison of various conceptions of levels of literacy

Arons (1983) knowledge in general	Uno & Bybee (1994) Biological literacy	Osborne (2002) Literacy in general	Hodson (2003) Science literacy	Carnine & Carnine (2004) General literacy
Figurative or declarative: Knowing "facts".	**Nominal** students can recognise some terms and know what area biology covers	Able to read & write your own name		Knowledge of concepts within content discipline areas
	Functional Can define terms but don't understand them. They have no idea of how concepts fit together	Read without understanding the import of what you are reading, recitation of facts without understanding them;	Understanding that science has an impact on society & that science and technology are culturally determined.	Application of science process skills
Operative or procedural: Knowing the source of declarative knowledge and using knowledge in unfamiliar situations.	**Structural** understand major conceptual schemes of biology. See schemes (unifying principles) as branches of the tree, evolution being the main trunk.	Comprehend unfamiliar material – need to understand a wide range of concepts	Recognising that scientific & technological development are linked to the distribution of wealth and power & benefit specific persons or companies.	The use of high-level reasoning within instructions
	Multidimensional broader interconnected understanding of biology.	Justifying ideas and relating them to other concepts and critiquing what is presented is the highest level.	Developing one's own views and establishing one's own underlying value positions.	
			Preparing for and taking responsible action.	

Knowing 'facts' does not make a person scientifically literate (Carnine & Carnine, 2004; Osborne, 2002; Uno & Bybee, 1994; Arons, 1983), and yet only Hodson's (2003) classification focuses on how knowledge is used. As Hodson (2003) points out, scientific literacy should be extended to include some measure of political literacy, or as Jensen & Schnack (2006:473) state, "education for democracy, or political liberal education, is, in itself, a fundamental educational task." The following questions should be asked when teaching any science subject, "How do you know....?", "Why do we believe...?" and "Who benefits by...?" (Jensen, 2004; Peacock, 2004; Roth, 2003; Battersby, 1999; Breiting & Mogensen, 1999; Ford, 1998; Arons, 1983; Karplus, 1962).

The following list contains some characteristics of a scientifically literate person:
A scientifically literate person

- understands which questions can be investigated by science and which questions science does not ask or answer, and knows how the knowledge obtained by scientists is verified (Cooper, 2004; Roth, 2003; Hodson, 2003; Grinnell, 2000; McComas, 1996; Arons, 1983).
- understands that scientific concepts and theories can change and be reviewed and refined as new information becomes available. Scientific knowledge is thus tentative and always subject to review (Yore, Florence, Pearson, & Weaver, 2006; McComas, 1996; Pollak, 1993; Arons, 1983; Karplus, 1962).
- knows that scientific language has very specific meanings that are not to be confused with the everyday use of the term (Osborne, 2002; Carlson, 2000; Simmich-Dudgeon & Egbert, 2000; Arons, 1983).
- is aware that evidence and argument are essential to science (Yore *et al*, 2006; Osborne, 2002; Grinnell, 2000).
- can read, interpret and evaluate reports in the media of scientific findings (Osborne, 2002; Ford, 1998; Shamos, 1988).

- can use the science they have for social purposes (Cooper, 2004; Jensen, 2004; Lee & Roth, 2003; Hodson, 2003; Battersby, 1999; Breiting, & Mogensen, 1999).

More than all these characteristics, Roth (2003) argues that scientific literacy involves getting access to means of communicating one's ideas and negotiating opportunities to speak. He believes that if access to the conversation is denied then scientific literacy cannot be developed. Preventing people from voicing their doubts and dismay at certain actions is an attempt to channel the path of scientific literacy in a certain direction. Knowing how to gain access and manoeuvre around blocks to make the objections heard is also part of scientific literacy (Roth, 2003; Hodson, 2003). This is the type of political literacy referred to by Hodson (2003). Schools are actually responsible for maintaining the status quo of society (Hodson, 2003; Burniske, 1998; Giroux, 1988), and thus learners must be taught to question so that schools become "democratic public spheres" and learners are educated in "transformative action" (Giroux, 1988). Democracy involves debate, but, as Burniske (1998) points out, there is no longer a healthy debate on issues of importance because big business corporations now own the media.

My question here is, "Are South African teachers capable of allowing learners to become scientifically literate, when they themselves have been denied the right to speak for so long?"

3.3 Teaching for Scientific Literacy

The aim of teaching any science subject should be to produce a scientifically literate person (Jordan & Duncan, 2009; Lang, Drake & Olson, 2006; Roth, 2003; Demastes & Wandersee, 1992; Karplus, 1970). Why does one need to be scientifically literate when many people are very successful, in business and other fields, without understanding anything about science (Shamos, 1988)?

Shamos (1988) gives four commonly-held reasons why a population should be scientifically literate, some of which are validated by other researchers.

Firstly, scientifically literate people can think critically and are therefore less likely to allow themselves to be deceived by politicians and charlatans, and to lead the lives of ignorant consumers (Eshach & Fried, 2005; Jeevanantham, 2005; Hodson, 2003; Shamos, 1988). But Shamos (1988) disagrees with this reason and points out that even scientists themselves disagree with one another on science-based policy issues. The issue here is the ability to question, particularly what one is told by politicians, which is a skill that underpins scientific thinking. McLaren (foreword to Giroux, 1988) believes the goal of all education is to prepare "all students to be active, critical, and risk-taking citizens" in a democratic society. Even if scientists disagree with one another, they are not likely to go blindly where a politician or businessman leads.

Secondly, scientific literacy is believed to prepare one for business and professional life. Here Shamos (1988) merely asserts that one only needs to look around to see the fallacy of this belief.

The third reason given is that there will be a future shortage of scientists if we do not train more scientists. Once again Shamos disagrees, and perhaps he was correct in 1988. However, there is a recognised shortage of scientists and engineeers in South Africa at present (Merten, 2011).

The final reason commonly held for the need for scientific literacy is that we need workers who can handle computers and robots in the workplace (Shamos, 1988). Actual scientific literacy is not what is necessary to use a computer. As Shamos (1988) points out, we have learned to use all sorts of technologies without any understanding of the science behind them. For Shamos (1988) the only valid reason for studying science is the one given by Jules-Henri Poincaré, whom he quotes, "because he delights in it, and he delights in it because it is beautiful" (Shamos, 1988: paragraph 27).

A reason not considered by Shamos but given by Peacock (2004) is that a scientifically literate population would be more likely to be aware of the impact that humans have on the environment and the social issues involved in science. They would thus be more likely to support measures to protect the environment (Peacock, 2004).

The science education we have at present is what Roth (2003) and Giroux (1988) call a form of indoctrination so that young people will not question the presuppositions that underlie science. Roth (2003) notes that in society we notice that drugs are removed from the shelves after a few years because they are eventually connected with causing cancer. Genetically-modified organisms are developed, and when questions are asked about them we are told that scientists know best. Do they? Where is the mechanism to hold them accountable for their actions (Roth, 2003)? Current practices in science education focus on "conformity to authoritative knowledge". Students are expected to conform and to reproduce what they have been taught (Lee & Roth, 2003; Giroux, 1988).

Shamos (1988:paragraph 28 & 29) notes that the first contact children have with science is fascinating, but as time goes by the emphasis changes to memorising facts – children lose interest and "the magic wears off and is replaced by boredom or, worse, outright rejection". Thus we should rather

> nurture an *appreciation* of science and thereby keep open the possibility of full literacy for some individuals than to force-feed facts and formulas and thereby instill a distaste for science that probably guarantees life-long ignorance.

The traditional way of teaching about the environment gives learners the "facts" about how bad the state of the environment is and what the problems are, but it fails to give any indication of the underlying causes or that this state of affairs can be changed (Jensen, 2004; Hicks & Bord, 2001; Giroux, 1988). This approach leads to the "individualization trap", where the individual problems are dealt with in isolation from others (Uzzell, 1999). The traditional approach is what Jensen (2004) terms the "scientific approach", and it leads to "action paralysis" and a feeling of powerlessness (Jensen, 2004; Hicks & Bord, 2001; Mogensen, 1997). Learning facts and concepts tends to overwhelm students but, according to Hicks & Bord (2001), teachers need to include the other dimensions of human experience if they want to empower students. Students need to work through the emotions they feel when presented with "facts" and "question their own values life-purposes, faith and ways of living", and, having done this, they will come to an "empowerment dimension" which enables them to see the possibility of change and thus leads to the action dimension (Hicks & Bord, 2001). To overcome this, the "discourse of despair" that results from all the problems raised, Giroux (1988) recommends that the language of critique be linked to the language of possibility, while Jensen (2004) recommends bringing in the knowledge that comes from the humanities to teach learners how to approach social problems. Jensen (2004:405) states that

> if environmental problems are to be solved in the long run, teaching is needed that contributes to the development of students' abilities to influence local and global environmental problems, i.e. teaching should develop students' abilities to take action themselves, that is their *action-competence*.

"Action-competence" is an approach that emphasises "interdisciplinarity, participation and action-orientation" (Jensen, 2004:406). Action-competence is the

> ability and will to take part in democratic processes concerning man's exploitation of and dependence on natural resources in a critical way (Breiting & Mogensen, 1999:350).

Action-competence seeks to involve all stakeholders and allow for democratic decision-making; thus communities take responsibility for doing what is necessary (Fien & Skoien, 2002). Learners must thus be able to see the possibility of change and be allowed to work towards change. This is achieved by allowing them to select problems that are important to them, and to work on finding solutions to these problems (Jensen, 2004). The Action-Competence model has eight steps:

1 Choose the problem of interest;

2 Define it carefully so that it can be operationalised;

3 Identify the causes of the problem;

4 Note what it is that must be changed;

5 Decide what can be done about the problem and how should it be done;

6 Specify what makes change difficult;

7 What action is needed most urgently?

8 Select appropriate actions that are sustainable.

(Jensen, 2004; Uzzell, 1999).

However, as Jensen & Schnack (2006) emphasise, this approach does not mean that the school is responsible for solving the problems of society. When learners have developed action-competence they will have reached the final stage of Hodson's (2003) level of scientific literacy. The next section shows that the curriculum could have produced ecoliterate learners if it had been properly implemented.

3.4 Learning Outcomes for Natural Sciences and Life Sciences

3.4.1 Natural Sciences

South African schooling is divided into two bands; General Education and Training band (GET), from Grades 1 to 9, and the Further Education and Training band (FET), which covers Grades 10 to 12.

In the GET band Natural Sciences are studied. The Revised National Curriculum Statement (RNCS) for the Natural Sciences is built around three Learning Outcomes (DoE, 2002a). They are:

> Learning Outcome 1 The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific and technological and environmental contexts.
> Learning Outcome 2 The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.
> Learning Outcome 3 The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. (DoE, 2002a:6)

Each Learning Outcome (LO) includes the environment, thus the importance of the environment is established. The kind of learner envisaged in the NCS is one who will

> act in the interests of society based on respect for democracy, equality, human dignity, life and social justice…a lifelong learner who is confident and independent, literate, numerate, multi-skilled, compassionate, with a respect for the environment and the ability to participate in society as a critical and active citizen. (DoE, 2002a:3)

It is particularly Learning Outcome 3 which could promote Action-Competence. To achieve Learning Outcome 3 learners in Grades 4 to 6 must understand "science and technology in the context of history and indigenous knowledge" and "the impact of science and technology" and "recognise the bias in science and technology" (DoE, 2002a:40, 41, 42). Learners in Grades 7 to 9 must understand "science as a human endeavour" and "understand sustainable use of the earth's resources" (DoE, 2002a:58, 59). These requirements would address the questions "How do you know….?", "Why do we believe…?" and "Who benefits by…?" These requirements would lead to learners being ecoliterate.

3.4.2 Life Sciences

The National Curriculum Statement (NCS) for Life Sciences (implemented in 2004) is also built around three Learning Outcomes, and they are very similar to those for the Natural Sciences. They are:

- Learning Outcome 1 The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem solving, critical thinking and other skills.
- Learning Outcome 2 The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.
- Learning Outcome 3 The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences, and the interrelationship of science, technology, indigenous knowledge, the environment, and society. (DoE, 2003:12)

Learning Outcome 1 for Grades 10 to 12 covers the topics that will be investigated. These include the typical types of investigation and dissections of various organs, microscope work, and literature searches into topics such as the latest medical practices, but they also include "Investigation of human influences on the environment … management and maintenance of natural resources" and the "Investigation of a local environmental issue, problem solving and decision making." (DoE, 2003:37). This should build Action-Competence.

Learning Outcome 3 deals with issues arising from how science is applied, and the impact of those applications on society and the environment. It includes life-support systems, sperm banks, surrogate motherhood, "test tube babies, abortion and ethics", "Exploitation vs. sustainability", the impact of industry, and "Land issues (e.g. ownership and use of land, nature and game reserves, agriculture, desertification, forestation/deforestation, urban decay)." Such topics should make learners aware of social issues.

The NCS for Life Science was revised and the new Curriculum was implemented from the beginning of 2008. The Learning Outcomes are given as follows:

- LO1: Investigating phenomena in the Life Sciences:
  Life Sciences focuses on exploring and investigating phenomena in the Life Sciences using inquiry, problem-solving and critical thinking skills. These include diverse ways of collecting data, analyzing data, reporting results and drawing valid inferences and conclusions from the data collected. Life Sciences investigates living systems through a range of different techniques, and learners will acquire investigative skills relevant to each knowledge area.
- LO2: Constructing Life Sciences knowledge:
  The learner is able to demonstrate construction, acquisition, understanding and application of Life Sciences facts and concepts to explain phenomena relevant to Life Sciences.
- LO3: Applying Life Sciences in society:
  The learner shows understanding of: the history of some scientific discoveries, the nature of science, how indigenous knowledge relates to living systems, applications of Life Sciences in industry, career opportunities in Life Sciences, and how Life Sciences is applied in everyday life. (DoE, 2007: 4 & 5).

The scope of Learning Outcome 3 is no longer as broad or as relevant as it was in the previous NCS. The most significant change in the Learning Outcomes is the omission of "the environment" and "ethics and biases" from Learning Outcome 3. So once again the focus has been shifted to "facts" and away from issues.

At the end of 2010 the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2010) was brought out to replace the NCS 2007 in 2012. Specific Aims replaced Learning Outcomes. Specific Aim 1 is very similar to Learning Outcome 2 and deals with "Acquiring knowledge of the Life Sciences (concepts, processes, phenomena, mechanisms, principles, theories, laws, models etc.)". Specific Aim 2 is similar to Learning Outcome 1 and deals with investigating phenomena in the Life Sciences. Specific Aim 3 represents a major shift from the original Learning Outcome 3, as can be seen in Table 3.2 below.

Table 3.2 A comparison of the wording of Learning Outcome 3 and that of Specific Aim 3.

Learning Outcome 3	Specific Aim 3
(The original 2003 wording) The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences, and the relationship of science, technology, indigenous knowledge, the environment and society. (DoE, 2003). **(The revised 2007 wording)** The learner shows understanding of: the history of some scientific discoveries, the nature of science, how indigenous knowledge relates to living systems, applications of Life Sciences in industry, career opportunities in Life Sciences, and how Life Sciences is applied in everyday life.	**(Wording taken from the final draft for comment 2010)** Appreciating and understanding the importance and applications of life sciences in society. (DBE, 2010:11). This includes: Understanding the history and relevance of some scientific discoveries, relating Indigenous Knowledge to the Life Sciences and recognising the "value and application of Life Sciences knowledge in industry", which is "about the applications, impact and relevance that the knowledge of Life Sciences has found in various aspects of society." (DBE, 2010:12)

This represents a major shift towards the interests of industry, and the environment is totally ignored. According to Giroux (1988), the alignment of the curriculum with the interests of industry undermines democracy. This change in emphasis was intentional, as shown by the comments made by the Acting Director-General of the Department of Higher Education in a newspaper article. The issues mentioned in the extract deal with job creation and what industry and business expect from new recruits.

> The new skills-development approach we are now driving seeks to address exactly these issues. Such an approach, which seeks to bridge the gap between merely theoretical qualifications and practical exposure, cannot be dismissed as an approach that will destroy workplace training. .... Their qualifications must also address the needs of business, which means including exposure to practical workstreams, gained from spending time in the relevant workplaces. ...New entrants should graduate with exposure to the workplace instead of mere theory. (The Mail & Guardian, June 3-9 2011:34).

Once again our politicians have, as Burniske (1998:156) points out, "mistaken job training for education". With this shift we are back to where we were before "the advent of democracy in South Africa". All these changes have merely made more work for teachers without necessarily improving the quality of science education.

Chapter 3 focused on defining scientific (?), eco-literacy and bioliteracy in the context of the National Curriculum statement for Life Sciences, and has shown that if Curriculum 2005 had been properly implemented we would have produced learners who are ecoliterate.

In Chapter 4 the methods used in this study are explained.

CHAPTER 4: METHODOLOGY

4.1 Introduction

This chapter will discuss rigour in qualitative research and explain the reason for selecting a case study approach, and will then explain how the following questions were answered:

2. Is the teaching of ecology addressing important issues relevant to South African problems as suggested in the curriculum?

3. What is the range of teaching strategies used by teachers to teach ecological concepts, and do these strategies develop ecological concepts adequately?

4.2 Rigour in qualitative research

"Without rigor, research is worthless, becomes fiction, and loses its utility" (Morse, Barrett, Manyan, Olson & Spiers, 2002:2). There are well-defined ways of determining the rigour of quantitative research, but it is more difficult to determine what constitutes rigour in qualitative studies because the procedures for assessing rigour are not standardised to the extent that they are for quantitative research (Gibbert & Ruigrok, 2010; Ashworth, 1997b). In fact, to impose such prescribed procedures on qualitative research would be counter-productive (Barush, Gringeri & George, 2011; Freeman, de Marrais, Preissle, Roulston, & St Pierre, 2007). However, Tracy (2010) feels that there are at least eight criteria that all types of qualitative research can fulfil without in any way limiting the researcher's activities. These will be discussed briefly in section 4.2.6. Other views of qualitative research are discussed below.

Shank & Villella (2004) use the following metaphor to illustrate the difference between quantitative and qualitative research. Quantitative research is like a window. It tries to give a clear, accurate and transparent view. To give an accurate view it must be reliable, valid, free of bias, and it must be possible to make generalisations from the research. Qualitative research is like a lantern. It will look in dark corners.

The criteria for determining rigour should therefore not be the same as for quantitative research.

According to Cutcliffe & McKenna (1999) there are four ways of approaching the question of rigour in qualitative research:

- Qualitative research should be judged by the same standards as quantitative research;
- It is impossible to use any criteria to judge the quality of qualitative research;
- Quantitative research should be used to test the theory that emerges from a qualitative study, and,
- Qualitative research should be judged by criteria developed specifically for its needs.

When we attempt to address issues of the quality of qualitative research in terms that are used for quantitative research we actually limit the value and scope of qualitative research, because qualitative research does not serve the same function as quantitative research (Barush *et al*, 2011; Freeman *et* al, 2007; Shank & Villella, 2004). Attempts to apply the criteria of quantitative research have led to the development of a parallel set of criteria, where 'validity' becomes 'soundness' or 'truth value' (Cutcliffe & McKenna, 1999; Andrews, Lyne, & Riley, 1996; Lincoln & Guba, 1985). 'Reliability' becomes 'trustworthiness' (Golafshani, 2003; Lincoln & Guba, 1985). Statistics cannot be used to determine 'truth value' or 'trustworthiness' or 'transferability', so the problem of demonstrating the quality of qualitative research remains.

It is however essential to ensure some form of rigour, otherwise the research will be meaningless fantasy (Morse *et al*, 2002; Cutcliffe & McKenna, 1999); so the second approach does not appear to be one that can be seriously considered. The suggestion of the third approach, that the only way to determine the rigour of qualitative research is to test the emerging theory using quantitative research, is to condemn qualitative research to be 'second-best practice' and to deny its value (Stoecker, 1991).

How then should rigour be ensured in qualitative research? Ways of ensuring rigour should be built into the research from the beginning (Morse *et al*, 2002). The first aspect of rigour to be looked at should be that the method chosen should be the most appropriate way of answering the research question (Ercikan & Roth, 2006; Morse *et al,* 2002; Gillham, 2000). Section 4.3 addresses this concern by demonstrating why using a case study was the best way to answer the research questions.

Ways of demonstrating qualitative rigour include:

- triangulation (Barush *et al*, 2011; Gibbert, Ruigrok & Wicki, 2008; Ruddin, 2006; Golafshani, 2003; Gillham 2000; Mays & Pope, 2000; Cutcliffe & McKenna, 1999; Patton, 1999; Ashworth, 1997a; Stoecker, 1991; Lincoln & Guba, 1985);
- leaving an audit trail or chain of evidence (Barush *et al*, 2011; Gibbert & Ruigrok, 2010; Buskens, 2002; Morse *et al*, 2002; Cutcliffe & McKenna, 1999);
- reflexivity (Barush *et al*, 2011; Buskens, 2002; van der Mescht, 2002; Mays & Pope, 2000; Ashworth, 1997a; Schutz, 1994), and
- thick description (Barush *et al*, 2011; Ercikan & Roth, 2006; Lincoln & Guba, 1985).

4.2.1 Triangulation

Gillham (2000) describes triangulation as "taking different bearings". The term comes from land surveying. There are at least four types of triangulation, namely, methods triangulation using more than one method of data collection (Gibbert & Ruigrok, 2010; Golafshani, 2003; Mays & Pope, 2000; Patton, 1999); looking at several sources of data or triangulation of sources (Mays & Pope, 2000; Patton, 1999); using a number of people to analyse the same data or triangulation of analysts

(Barush *et al*, 2011; Patton, 1999); using different theories to interpret the data (Barush *et al*, 2011; Patton, 1999). Van der Mescht (2002) argues that triangulation cannot make the picture more valid. It can merely make the picture more complete. Triangulation attempts to reduce systematic bias in data (Golafshani, 2003; Patton, 1999), but Bergman & Coxon (2005) believe that while there is an objective reality that exists despite us, we must try to capture that reality through observation. This means that we try to translate it into what we can understand, which is bound by our contexts and is definitely subjective. So what we report remains subjective, despite our attempts to remove bias. I used method triangulation, and my data sources were classroom observations, informal discussions with teachers, and the misconception questionnaire. Bearing van der Mescht's (2002) objections in mind, I saw triangulation as a way of looking for inconsistencies in the picture presented by the respondents, and those inconsistencies were then probed so that the respondents' actual views could be clarified. When a picture is more complete it is easier to pick out inconsistencies (Mays & Pope, 2000). Patton (1999:1193) maintains:

> However, a common misunderstanding about triangulation is that the point is to demonstrate that different data sources or inquiry approaches yield essentially the same result. But the point is really to test for such consistency.

Finding inconsistencies needs not weaken credibility, because differences can be expected since different kinds of data will give slightly different results, but researchers must be able to understand what those differences mean (Patton, 1999). Van der Mescht (2002) warns that qualitative researchers tend to claim that they are triangulating findings with three sets of data (questionnaires, observations and interviews), but they rarely relate the various sets of findings to one another and usually report on them separately. I have attempted to link all data collected to the conceptual framework of bioliteracy, so that all data is used to determine the levels of bioliteracy.

4.2.2 Audit trail

An audit trail or chain of evidence is a record of all decisions taken and of the researcher's approach to problems experienced (Gillham, 2000; Cutcliffe & McKenna, 1999). This helps to ensure the technical quality of the work (Buskens, 2002), but Morse *et al* (2002) feel that an audit trail may give proof of decisions but does not identify the quality of those decisions or the rationale behind them. I have attempted to explain what changes were made and how the decisions were reached. I kept field notes to record happenings while doing classroom observations.

4.2.3 Reflexivity

> Given the acknowledged subjectivity of qualitative methods and the importance of the researcher's lens, we strongly encourage that the simple task of presenting the researcher's relevant traits be undertaken more often (Barush *et al,* 2011:17).

My 'relevant traits' are presented in Section 4.6.5. Reflexivity involves the researcher in pausing for periods of reflection on his/her role in the research process and his/her actions in the process (Buskens, 2002; Patton, 2002; Mays & Pope, 2000; Ashworth 1997a & 1997b; Schutz, 1994). Researchers need to ask themselves why they are doing what they are doing and what should be done next. Keeping a diary helps with reflexivity (Buskens, 2002; Ashworth 1997a). Buskens (2002:18) warns that we should not be too critical of ourselves. She says that we need "generosity of spirit, compassion for the self, self-forgiveness, perseverance, and a good sense of humor" when we engage in reflection. Researchers need to "stand back" and view their work critically (van der Mescht, 2002; Schutz, 1994). "They need to be clear what they are **not** doing (van der Mescht, 2002:50)."

4.2.4 Thick description

Holliday (2004:733) describes thick description as

> (T)hick description is a more creative device for piecing things together and understanding how things are interconnected – finding, describing, and understanding the interconnectedness of the diverse social elements of the setting as small culture that makes up the case study.

According to Barush *et al* (2011), thick description includes direct quotes to illustrate concepts that are relevant to the study and that describe the environment and the respondent's participation. However, van der Mescht (2002) claims that thick description is used to cover shoddy work. Cyrenne (2006:318) adds to the criticism of thick description by pointing out that we can never understand an insider's perspective, and warns that the extra detail "often obscures more than it reveals". In this study thick description refers to the descriptions of both schools at the beginning of the chapter reporting on the results for the school(s?).

The study is an exploratory study, and no statistical generalisations can be made from it. However, I have attempted to describe the schools clearly so that those in a similar position can make what generalisations they choose (Freeman *et al*, 2007).

4.2.5 Other means of imparting rigour to qualitative research

Tracy (2010) suggests eight "big tent" criteria for judging the quality of qualitative research which she believes can be applied to all qualitative research. The criteria are: having a worthy topic, rich rigour, sincerity, credibility, resonance, significance of contribution, ethical and meaningful coherence. Trustworthiness (includes credibility, transferability, dependability and conformability) is another very important way in which to substitute for quantitative design and measurement issues (Tashakkori and Teddlie, 1998). Conformability is important to establish trustworthiness of results and inferences. I had to make sure in this case that the respondents in the study were not providing information that was based on their being "good" informants, or because they were apprehensive or negative. I did this by ensuring that I checked my results with follow-up observations, interviews, and thick description.

I have tried to show in the literature review why I consider the topic of how ecology is taught in South African schools to be worthy of study. Under rigour, Tracy (2010) notes that variety provides richness. I have attempted to use a variety of settings –

primary school, high school and university. I have checked misconceptions of students by interviewing students to check that I interpreted their responses correctly. Sincerity is demonstrated through transparency and self-reflectivity (Tracy, 2010). I have reported on problems and tried to be transparent. Credibility is marked by thick description and triangulation, which have been discussed already. I do not know if I can claim resonance because, according to Tracy (2010), resonance moves readers and allows for naturalistic generalisations. I believe that naturalistic generalisations will be possible from this work. I also believe that shedding more light on the problems of teaching ecology does make a significant contribution. I have considered procedural ethics and ensured confidentiality as suggested by Tracy (2010). This study does connect literature, research questions, findings and interpretations, so it should be meaningfully coherent as advocated by Tracy (2010).

4.3 Case study

Is case study a method or a design? There are differences of opinion on this question. Stoecker (1991) maintains that case study is neither a method nor a design at present, but a "design feature" which determines the boundaries of data collection. Flick (2009) considers case study to be a research design, while Gillham (2000) considers it a method.

Case studies are used when phenomena are investigated in depth as they occur in their natural settings (Gibbert & Ruigrok, 2010; Ruddin, 2006; Torrance, 2005; Foster, Gomm & Hammersley, 2000; Gillham, 2000; Stoecker, 1991; Lincoln & Guba, 1985). This study was about the teaching of ecology. Since teaching cannot be separated from the context in which it occurs the best way to study it is to do a case study (Gillham, 2000). Case studies are good for studying "teacher-student interactions and teacher and student affect, motivation and energy" (Desimone & Le Floch (2004:3). A case study uses multiple sources of evidence, is flexible, and focuses on specific questions (Norrie, 2004; Stoecker, 1991).

By definition this study was a descriptive exploratory study because it dealt with something about which little was known (McMillan & Schumacher, 2001). There was very little in the literature that discussed the actual teaching of ecology in South Africa. This study attempted to answer the question, "What is happening in the teaching of ecology in South Africa?" According to Ercikan & Roth (2006) a case study is one of the best methods for answering that type of question. What *was* known about the teaching of ecology in South Africa was the content to be taught for ecology which was given in the Core Content in the National Curriculum Statements (DoE, 2003; DoE, 2002a), and the way in which the content was approached. The approach should have been influenced by Learning Outcome 3 (DoE, 2003), as shown in section 3.4. It was necessary to determine whether or not teachers approached the teaching of ecology in the manner suggested by Learning Outcome 3, and in such circumstances Gillham (2000) considers it best to do a case study.

4.4 How the research questions were answered

Table 4.1 Summary of how the research questions were answered

Question	Method of answering
1. How do teachers and learners navigate the terrain of ecology and what are the associated conceptual understandings?	Administered a misconceptions questionnaire to Grades 8-11 and first- year Life Science at University of the Western Cape. Interviewed nine of the university students to check misconceptions.
2. Is the teaching of ecology addressing important issues relevant to South African problems as suggested in the curriculum?	Classroom observations were done in classes from Grade 5 to Grade 11. The National Curriculum Statements were analysed to determine what was required.
3. What is the range of teaching strategies used by teachers to teach ecological concepts and do these strategies develop ecological concepts adequately?	Classroom observations were done in classes from Grade 5 to Grade 11. The questionnaire helped to determine whether the concepts were adequately developed.

The first question required that the conceptual understanding of both teachers and learners be measured; however, the situation did not allow for this. It would also have been inconsiderate to have been granted the little time I had to work in a teacher's classroom, and then to suggest that the teacher should write a test to see if he/she understood ecological concepts. Only the learners were tested, using a misconceptions questionnaire that will be described later in this chapter.

The term 'misconception' refers to "students' articulations that are not scientifically accurate (Bahar, 2003)". This term is used in this thesis in preference to the terms 'naïve conceptions' or 'alternative conceptions', because by the time learners have reached high school any conceptions that they have about ecology can no longer be termed 'naïve conceptions' since they have been taught ecology in primary school. 'Alternative conceptions' does not give any indication of the acceptability or accuracy of those conceptions, and has therefore not been used in this thesis.

The second and third questions were answered by analysing the curriculum to determine how it addressed ecology, and by doing classroom observations in order to compare the way in which teachers approached ecology, given what was required by the National Curriculum Statements for Life and Natural Sciences.

4.5 Sampling

Since an understanding of basic concepts in a subject is built gradually (Martin, Mintzes & Clavijo, 2000; Novak, 1998; Smith, DiSessa & Roschelle, 1993), the sample should have involved classroom observations and testing of the grades in which ecology was taught directly, i.e. Grades 4 to 12, but because the letter giving permission to do the research in schools (See Appendix A) stated clearly that researchers are not allowed into Grade 12 classrooms, no observations were done in a Grade 12 classroom.

It is clear that to answer the above questions properly would have required a large, representative sample. This was not possible because of the time constraints on a PhD study. However, Stoecker (1991) notes that single cases show up variables that are otherwise lost, so even though only two schools were studied they still provided evidence of how teachers experience the teaching of ecology. McMillan & Schumacher (2001) state that the sites selected should be suitable for research and feasible for the researcher's resources of time, mobility and skills. The schools selected were easily accessible to me. There was no other basis for choosing schools, since no school can be considered 'typical'. Any school selected would therefore give some indication of how teachers approach the teaching of ecology.

This study is a qualitative study using case studies of two schools. One primary school and one high school were chosen on the basis of their accessibility to the researcher, and their willingness to allow a researcher into their classrooms. Two high schools were approached before one was found that was willing to allow a researcher into the classrooms.

Unfortunately, between being given permission to study in the primary school selected and the actual study, the principal who had given permission for the study left, and the new principal was not favourably disposed toward having a researcher in the classrooms. It was thus not possible to answer the first of the research questions for the primary school, but some classroom observations were done. By that stage of the study it was too late to approach another primary school.

Shank & Villella (2004:52) note that

> Too much design interferes with the ability of the researcher to be flexible and to respond to change in an immediate fashion.

It was necessary to change, from using only school children for the study to include university students, because of the lack of access to Grade 12 learners and classes. In order to determine what the conceptual understanding of Grade 12 learners may have been, the misconceptions questionnaire was administered to 285, just under 47% of the class of first-year Life Science students at the University of the Western Cape. The questionnaire was administered in the week of January 25 to 29 in 2010 before the students had had any formal lectures. The students tested were those who had already registered.

The selection of questions will be discussed in a later section. The students complained that the questionnaire with eighteen questions was too long, hence a shorter questionnaire with ten questions was administered to the Life Science 142 and Biodiversity and Conservation Biology second-year students in the first week of the second semester, to see whether the misconceptions persisted after their being taught Life Science 141, which covered photosynthesis and respiration. The same shorter test was administered on 10 June 2010 to the nine volunteers from the Post-Graduate Certificate of Education (PGCE) course who were starting their practice teaching in July. This was done in order to see if pre-service teachers had misconceptions that they would carry into their teaching. The requirements for a PGCE course are that the students registered for the course have completed a bachelor's degree with courses in the subjects they plan to teach.

The first research question concerning the conceptual understanding of learners was thus answered by administering a misconceptions questionnaire. This was done in Grades 8 to 11, and Life Science courses with first-year students (141, 142, 151, 152), a second-year University course, (BDC 212), and with PGCE pre-service teacher volunteers.

The second and third research questions concerning the issues addressed in ecology lessons and the teaching strategies employed were answered by doing classroom observations in classes from Grade 5 to Grade 11 because, as Desimone & Le Floch (2004) have noted, to determine content covered in the classroom requires observation. How the observations were done will be described in section 4.6.3.

4.6 Data sources

4.6.1 The questionnaire

The questionnaire (Appendix E) was used because it was necessary to gather information about the general level of understanding of ecological concepts of a large number of learners in a short period of time. By that definition the questionnaire could be considered a survey (Pinsonneault, & Kraemer, 1993). A survey will give a quantitative description of aspects of the population. No statistics were used beyond simple percentages. The questionnaire was designed to reveal common misconceptions that learners may have about ecology. It was developed using misconceptions that were listed in the literature, e.g. Barman & Stein, 2008; Chiromo, 2001; Munson, 1994. The selection of items for the questionnaire will be discussed later in this chapter.

A common disadvantage of using questionnaires is the problem of non-response which could be because of population non-coverage, unit non-response, or item non-response (Tomaskovic-Devey, Leiter & Thompson, 1995). In the context of this research non-response of any form was not a problem. Some learners who were absent when the test was administered might have been missed, but their absence did not have much influence on the overall picture of misconceptions that was gained from four classes of 45-50 learners each. Items not responded to still gave an indication of a lack of understanding of ecological concepts, even though no indication of misconceptions was gained. Since the non-responses were genuinely random they did not affect the results negatively (Tomaskovic-Devey *et al*, 1995).

The questionnaire was given to four experts in the field of ecology for comment and to establish that the questionnaire itself was not transmitting misconceptions, and to comment on the questions. Content validity was therefore established.

Each item consisted of a statement with which the respondents had to agree or disagree. They were asked to provide a reason for why they agreed or disagreed with the statement. This had a two-fold purpose: to allow the researcher to get an insight into the student's understanding and to decrease the effect of guessing (Holtman, 2000). White, Jennings, Renwick, & Barker (2005) point out that open-ended questions allow for insight into thought processes. Insight into the thought processes of learners was the purpose of the open-ended section requesting a reason for agreeing or for disagreeing with the statement given. White *et al* (2005) warn that interviews give better insight into thought processes. Interviews, however, are time-consuming and do not allow one to get information about large numbers of people (Gillham, 2000). Interviews were used to check findings in a limited number of cases.

4.6.1.1 Piloting the questionnaire

The test was piloted with Grade 11 learners at a private school. The original plan had been to use the same test for Grades 8 – 11. The Grade 11 teacher at the school informed me that it would not be suitable for Grades 8 and 9. Thus Frazer & Lawley's (2000) advice, to pre-test using colleagues as well as respondents, was useful. A separate test was then set up for Grades 8 and 9, using the syllabus as a guideline for the topics they had dealt with (Appendix E).

According to Presser, Couper, Lessler, Martin, Martin, Rothgeb, & Singer (2004), pre-testing is usually a 'dress rehearsal' for the actual testing and is done in exactly the same way the questionnaire will be administered. In this instance the pilot was not administered in exactly the same way. Learners writing the pilot test were specifically asked to make comments about the wording of the questionnaire and the content of the statements. They were told to look for problems and to ask questions if the wording was not clear, so as to be sure that they understood the statements in the questionnaire (Collins, 2003). They were also told the purpose of the test. This avoided the problem raised by Presser *et al* (2004:111), that conventional pre-testing is more likely "to identify problems the questionnaire poses for the interviewer" than to find out what problems the respondents may have. Collins (2003) advises checking that the respondent understands the question in the same way as the researcher to avoid errors, but this was not really possible for this questionnaire, since it was going to be administered to students from all demographic population groups. To overcome this, students were told to ask for clarification if they did not understand the question.

The results of the pilot revealed (see Appendix B) that one question on 'carrying capacity' had to be removed because that would only be taught in Grade 12. Learners also do not have an adequate understanding of 'limiting factors' because the concept is not mentioned anywhere in the syllabus.

4.6.1.2 Selection of items for the questionnaire

Some of the statements used in the questionnaire (found in Appendix B) contained the correct concept, so that there were statements that the students could legitimately agree with.

1 *Respiration only takes place in animals; plants have photosynthesis instead of respiration.*

This is a common misconception according to Sundberg & Moncada (1994). Various authors suggest that it is the result of a superficial comparison of photosynthesis and respiration, which takes note of the gas exchange but ignores the intricate biochemical processes that use the gases (Köse, 2008; Kao, 2007; Amir & Tamir, 1994). Eisen & Stavy (1988) found that even some students who have biology as a major believe that photosynthesis is the plant's way of breathing.

Although photosynthesis and respiration appear to be questions of physiology, an understanding of these concepts is essential to understanding how ecosystems function (Çepne, Taş & Kőse, 2006; Eisen & Stavy, 1988). The following statement by Çepne *et al* (2006:193) emphasises this point:

Even more importantly, an understanding of photosynthesis and respiration is a pre-requisite for any systematic understanding of ecology. Food chains and food web begin with photosynthesis and end in respiration. The photosynthesis and respiration play essential roles in the flow of energy through ecosystems.

2a The piloted questionnaire had the following question listed as number 2: "Carnivores have more energy or power than herbivores do" (Chiromo, 2001). This was removed from the final questionnaire because one of the experts consulted felt that the language was too vague.

2 *Plants do not use nitrogen.*

An understanding of biogeochemical cycles is necessary to the understanding of how an ecosystem functions. In the syllabus, water, oxygen, carbon and nitrogen cycles are required (DoE, 2007). Stamp, Armstrong, & Biger (2006) mention that there are misconceptions about nutrient cycling, without elaborating on what those misconceptions are. This prompted the inclusion of an indirect question on nutrient cycling. If learners do not know how organisms use nitrogen they are unlikely to see the need for the nitrogen cycle (Chiromo, 2001). Another aspect of understanding the biogeochemical cycles, mentioned by Eyster & Tashiro (1997), is that an understanding of these cycles is important to recognising the impact of nutrient changes on interactions within an ecosystem and understanding the concept of 'limiting factors'. Eyster & Tashiro (1997) point out that students usually find studying biogeochemical cycles 'boring or confusing', little realising how important they are. It was thus likely that learners would not understand the need for nitrogen. Teachers themselves find nutrient cycling the most difficult to teach (Wagiet, 1991).

3 *A cow is a producer within the food chain because it produces milk and meat which we eat to make us strong.* This statement was given as an actual response to an interview question by Chiromo (2001) asking them to identify a producer. The learner justified this response by saying that a producer was anything that could be eaten by another organism. This problem may be related to the fact that many learners, when asked what a producer produces,

will answer "food" (Eisen & Stavy, 1988). If this is so then a cow can be said to produce food. Eisen & Stavy (1988) note that students have difficulty believing that a gas, CO_2, can be used to produce solid organic material.

4a The piloted questionnaire contained the following question, "Carrying capacity does not remain constant for a given environment (Munson, 1994) This item was removed because 63% of the learners in the pilot run did not respond to this question.

4 *If plants, seaweeds and phytoplankton disappeared from the earth and sea, I would eventually starve to death.* Twenty-three percent of the pre-service biology teachers in Barman and Stein's (2008) study felt that the disappearance of producers from the earth would have little effect on other organisms. Only 43% of the students sampled in their study realised that all animals are dependent on plants. Eisen & Stavy (1988) made the surprising find that even with biology majors, only 39% considered life without plants impossible. Most of these students tended to concentrate on the possible lack of "food" and neglected to mention the effect on atmospheric oxygen levels. While most students were aware of oxygen release during photosynthesis, they apparently could not apply this "fact" to their own lives and regarded it as irrelevant. This misconception reveals a total lack of understanding of the basis of life on earth.

5 *Populations increase until carrying capacity is reached and then they crash or go extinct.* Students tend to believe that populations either continued growing indefinitely or that they were in a constant state of decline (Munson, 1994). Few college students understand the concepts of carrying capacity or environmental resistance (Eyster & Tashiro, 1997). This statement was used in an attempt to determine whether or not the students had any conception of carrying capacity or of environmental resistance.

This question was omitted in the post-test as there is no mention of carrying capacity in the National Curriculum Statement, and it was clear from the pre-test that the learners did not understand the concept.

6a The piloted questionnaire contained the following question, "Tertiary consumers have the most energy because energy accumulates up the food chain (Chiromo, 2001)". This item was omitted from the final questionnaire because it dealt with the same concept as Question 18 and was felt to be unnecessary.

6 *A human baby, born normally, can never be identical to either of its parents.*

While this item deals with genetics it was used because it was relevant to the learners' understanding of evolution and natural selection. Among the most difficult things for students to understand in genetics is how chromosomes segregate during meiosis, and how this process relates to the formation of gametes and to an understanding of variation within a species (Stewart, 1982). Thirty percent of the students in Barman and Stein's (2008) study agreed that a baby could be identical to either of its parents. Elrod (2007) found that there was confusion about how characteristics were inherited. Students generally consider anything to do with genetics to be difficult (Lewis, Leach, & Wood-Robinson, 2000a; Bahar, Johnstone, & Hansell,1999). Bahar *et al*, (1999) explain that the areas of difficulty in science in general lie in three areas: Macro and tangible, Micro and molecular, and Representational/Symbolic. Observations of flowers or insects (the Macro) are accessible. Alleles and genes (the Micro) are not, nor are manipulations of symbols to show what happens to the Micro that gives rise to the Macro. Vocabulary must thus be explained carefully and symbolism must be introduced slowly (Bahar *et al*, 1999). Some students believe that information from the fertilised egg was shared out at each cell division, and most students could not differentiate between sperm cells and somatic cells (Lewis, Leach & Wood-Robinson, 2000b). These problems indicate that students are unlikely to understand how the genetic information in the baby's cells can differ from those of its parents.

7 *Plants have no means of defending themselves against herbivores.*

This misconception was noted by Stamp, Armstrong & Biger (2006) and D'Avanzo (2003). It prevents students understanding the co-evolution of plants and animals, and the "arms race" that exists between plants and herbivores. This question was left out of the post-test questionnaire because no misconceptions on this issue were found in the pre-test.

8 *The process of respiration provides plants with their energy.*

Most students in Lazarowitz & Lieb's (2006) study did not know that respiration produces energy. Sixty-four percent of the students studied by Lee & Diong (1999) believed that food provided energy, but since food is digested the students assumed that it was the digestion that actually provided the energy. There was no understanding of the role of respiration in the provision of energy. Many students believe that plants do not respire (Köse, 2008; Çepne, Taş, & Kőse, 2006). These studies confirm that what Treagust (1986) found is still applicable now. In his study students from years 8 to 12 did not have an understanding of respiration. Stewart (1982) provided a list of the most important and difficult concepts in biology, and respiration topped the list. Photosynthesis was sixth on the list. While this research can be considered outdated there is no evidence to show that this view of respiration has changed in any way.

9 *Animals can build their own carbohydrates from the food they take in.*

This item was included as a result of personal experience in teaching. In my classes learners had difficulty realising that while consumers depended on producers for their food, that food was used to build what the animals needed for their bodies. Learners tended to think that all food taken in was used for respiration. The question was omitted from the post-test because it confused the students, and they showed the same basic lack of understanding that the learners in the researcher's classes had done.

10 *Plants get their carbon from the soil through their roots.*

This common misconception was found by several authors (Köse, 2008; Çepne, Taş, & Kőse, 2006; D'Avanzo, 2003; Flores & Tovar, 2003; Mintzes & Wandersee, 1998). It can possibly be explained by the fact that students have difficulty believing that air which they think of as 'weightless' can produce biomass, hence their belief that plants get carbon from the soil through the roots (D'Avanzo, 2003; Eisen & Stavy, 1988).

11 *A population consists of all organisms living in a particular area.*

Chiromo (2001) found this to be a common misconception, with nearly 79% of the learners claiming that different organisms living in an area form a population.

12 *It is possible to have more consumers than producers.*

About two-thirds of the learners in Chiromo's (2001) study had never heard of an inverted pyramid of numbers and believed it to be impossible. This question was left out of the post-test because most of the learners had never heard of an inverted pyramid of numbers.

13 *Decomposers release some energy that is cycled back to plants.*

Students tend to confuse matter and energy, and hence assume that energy will be cycled through the system (D'Avanzo, 2008; Arons, 1983). Another misconception is that decomposers have no effect on the ecosystem because they are too small (Özkan, Tekkaya & Geban, 2004).

14 *Soil is a biotic component of the ecosystem because it gives food to plants.*

This was a poor question since it encompassed two misconceptions in one question, namely that soil is living and that it gives food to plants. This failing was not picked up when the questionnaire was trialled, nor was it noticed by the experts who checked the questionnaire. An inability to distinguish between biotic and abiotic may simply be the result of language problems, since many of those who answered the questionnaire were not English-speaking. Nevertheless there are students who, despite having been taught about photosynthesis, will still claim that most of the food of a green plant is obtained from the soil (Köse, 2008; Driver, 1991). This misconception could possibly come from gardeners' habit of saying that plants must be fed (Meyer, 1993). Barman & Stein (2008) found that 20% of the pre-service teachers believed that plants required fertiliser in order to grow. This item was omitted in the post test because it is too similar to item 10.

15 *An organism may occupy more than one trophic level in a food web.*

This misconception was noted by Chiromo (2001). Students clearly did not understand what an omnivore was. This was left out of the post-test questionnaire.

16 *Producers do not occur in water.*

This misconception was noted by Hershey (2004) and Chiromo (2001). Learners tend to believe that plants are land organisms. They ignore seagrasses and plants that live submerged in water (Hershey, 2004). Producers are not obvious in large bodies of water, and therefore learners may not be aware that they exist (Chiromo, 2001).

17 *Natural selection kills those individuals of a species which lack the characteristics that would have enabled them to survive and reproduce successfully in their environment.*

This misconception was taken directly from the National Curriculum Statement Grades R-9 Natural Sciences (DoE, 2002a:64). This statement is an anthropocentric explanation of natural selection, which is similar to the kind of explanations given by students that tend to presume that processes like evolution or even physiological pathways are directed (Gregory, 2009; Klymkowsky & Garvin-Doxas, 2008). Students cannot grasp the importance of random processes, and seek meaning or direction in all processes. This also encompasses the misconception mentioned by Nehm & Reilly (2007), that needs cause evolutionary changes to take place. Klymkowsky & Garvin-Doxas (2008) suggest the use of simulations to overcome this misconception. This was left out of the post-test because there was very little understanding of natural selection and the topic was not dealt with in the first semester, so no further understanding could have been gained from the lectures.

18 *Energy is lost at each trophic level of the food chain.*

The misconception about energy flow through the food chain was noted by Stamp, Armstrong & Biger, (2006); D'Avanzo, (2003) and Chiromo, (2001). Çepne *et al*, (2006) found that students have difficulty with the concepts of energy and nutrients. Other misconceptions that this statement could have shown are that since every living thing has its own energy, there is no need for energy to be passed from one organism to another (Özkan *et al*, 2004), and that those at the top of the food chain have more energy than the rest because they get energy from all the others (Özkan *et al*, 2004; Munson, 1994).

4.6.2 Interviews

Interviews were used to verify that students actually held the misconceptions that appeared in their responses to the questionnaire because, as noted by Desimone & Le Floch (2004), all surveys need to be checked. It would have been better to interview at least five students from each class, but this was not possible because only nine students from the list of those selected to be interviewed agreed to be interviewed. The students felt that there was nothing for them to gain by being interviewed and that their schedules were full, with no time available in which to be interviewed. Getting people to agree to be interviewed is a common problem experienced in research (Liedtka, 1992).

High-school learners were not interviewed, because the school term had been shortened to accommodate the Soccer World Cup in 2010 and the principal said that enough time had been lost. He also said that the learners should not be deprived of their break.

Interviews are a basic method of gathering information in qualitative research (Opdenakker, 2006; van der Mescht, 2002; Gillham, 2000; Liedtka, 1992). Interviews, according to Liedtka (1992:164), encompass "any face-to-face interaction in which questions are asked by one party and answered by another". Interviews may be structured, with carefully specified questions, semi-structured with suggested questions which may be changed, or unstructured with open-ended questions (van der Mescht, 2002; Liedtka, 1992). Open-ended questions are best to get the most information (Gillham, 2000; Britten, 1995). While interviews are a rich source of information they are extremely time consuming, and a one-hour interview can take from six to ten hours to transcribe and analyse (Opdenakker, 2006; Gillham, 2000).

The interviews conducted in this study were in-depth interviews which focused on one or two issues (Britten, 1995). Each interview was designed to elicit the misconceptions held by the student being interviewed, thus each interview used a different set of questions which were based on the answers given in the misconceptions questionnaire. There was thus no interview schedule with a predetermined list of questions to be asked of all students. During the interviews new questions were included, if the interviewee's answers needed to be interrogated to ensure that they had been correctly interpreted (Britten, 1995). As Liedtka (1992:166) states:

> Rather than standardizing, questions and probes are personalized to enhance rigor – which is aimed at establishing the validity of the researcher's ultimate interpretation.

Opdenakker (2006) warns that this freedom to ask probing questions comes with the disadvantage that the interviewer may be so busy formulating questions that he/she forgets to listen carefully. To avoid missing any misconceptions all interviews were taped, with the permission of the interviewees. The interviews aimed to confront misconceptions and make the students think about their misconceptions, so in that sense they were what Roulston (2010) terms "transformative interviews". The interviews could also be considered "actively confronting interviews", as described by Kvale (2006), because the students' answers were challenged in an attempt to reveal misconceptions.

The interviews were transcribed as soon after they had taken place as possible because memory helps decipher what was said (Gillham, 2000). Because these interviews were focused on each student's misconceptions, there was no interview schedule with set questions.

4.6.3 Classroom observations

Experts observing the same lesson would rate it differently, therefore the purpose of the observations needs to be made clear and an observation schedule needs to be designed to suit the purpose of the observation and to avoid subjectivity (Sullivan, Mousley & Gervasoni, 2000; Croll, 1986). This was a qualitative research study, so subjectivity was acknowledged to be part of the study. The researcher's views are made explicit in section 4.6.5, as McMillan and Schumacher (2001) advocate. I felt that a well-defined observation schedule with predetermined categories would help to focus my attention during the lesson. It would also serve to refresh memory when analysing data. Croll (1986) advocates using an existing observation schedule if possible. He notes that pencil and paper recording, together with some form of time-keeping device, is less intrusive in most classroom situations. I did not do video recordings or audio recordings of the lessons observed as I felt that they would be very intrusive and distract the learners. I only used my watch and the schedule developed by Johnson, Scholtz, Hodges and Botha (2002). The observation schedule is found in Appendix C. According to McMillan and Schumacher (2001), this style of analysis is technical/objectivist because outside criteria are imposed on the data. This in no way detracted from the qualitative study, since the categories used allowed interactions between the teacher and learners to be noted.

In this study I was a participant observer (Patton, 2002; Gillham, 2000) because I taught parts of some lessons. This was done at the invitation of the teachers concerned. Patton (2002) notes that participant observation exists on a spectrum from complete separation through to complete immersion in the situation. The extent of participation changes over time (Patton, 20002; Schutz, 1994). In the beginning I was just an outside observer, but after observing a few lessons three of the teachers asked me to teach a section of a lesson for them. I was never completely immersed in the situation. Participant observation allows the researcher to discard his/her prior conceptions of what the situation is. It allows the researcher to engage in informal discussions with those being observed, and thus enables the researcher to learn things that people would be unwilling to talk about in an interview (Patton, 2002).

4.6.4 Curriculum analysis

In order to determine what was required by the curriculum an analysis of the curriculum was done.

A curriculum is a written description of the purposes, range, and sequence of the disciplinary content to be studied (Beauchamp, 1982). Because the end-users are not the people who design it, the actual curriculum that is experienced in the classroom by the learners will be different to the ideal planned by the developers (Morris, 1955), hence we have the distinction between Ideal curriculum, Intended curriculum and Received curriculum (McComas, 2003) or, as Amaral & Garrison (2007) termed it, the Intended, the Implemented and the Achieved Curriculum. The basic distinction between what was planned, what was taught, and what was learned remains, even though the terms used for each differ from one author to the next. For simplicity I will use Amaral & Garrison's (2007) classification. The intended curriculum is the curriculum as envisaged by those who developed it, the implemented curriculum is what the teachers think they are providing, and the achieved curriculum is what each child actually experiences.

South Africa has an outcomes-based curriculum, which Ornstein & Hunkins (2004) classify as a behaviourist curriculum because it is logical and prescriptive and defines the outcomes beforehand. They maintain that outcomes-based curricula are influenced by business and industry. Curriculum documents were studied to determine the planned curriculum. This was difficult, as a revised curriculum for the FET band was introduced at the beginning of 2009 and yet another revised curriculum was introduced at the beginning of 2011. Classroom observations, done in 2010, determined whether the requirements of the 2003 and the 2009 curricula were met.

This analysis revealed that what McComas (2003) called "an eco-ethical" approach was the intended curriculum. The impact of human actions on the environment was important, as demonstrated by the wording of Learning Outcome 3 in the 2003 curriculum:

> The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences, and the relationship of science, technology, indigenous knowledge, the environment and society. (DoE, 2003).

Unfortunately this emphasis was removed from later revisions, as shown in Table 3.2 in the previous chapter, which left out references to ethics, biases and the environment and in so doing changed the emphasis to one emphasising "facts".

4.6.5 The researcher

The style of writing a thesis is determined by the assumptions underlying the inquiry. If it is assumed that the research is 'objective' and can be replicated by another researcher, then the thesis will be written in the passive voice. "The writing uses passive voice, or de-personalizes the actor in the research to be 'the study'" Yates (2004:78). If, on the other hand, the research is qualitative, it will need to be written so that the voice of the researcher is heard. There will be sections written in the first person so that readers will become aware of who the researcher is and how the researcher entered the field. The readers need to see how the researcher deals with his/her subjectivity. Yates (2004:78, 79) observes:

> In studies like this, first-person accounts would usually be seen as essential, because passive voice would indicate that the researcher was not thinking enough about their own impact on the object of study and was not scrutinizing sufficiently critically what happened in the field.

The purpose of the above is to show why I have departed from the usual practice of writing in the third person.

The researcher is an instrument in the research process and is valuable in evaluating the meanings of interactions (Jacobson, Gewurtz & Haydon, 2007; Ercikan & Roth 2006; Hemmings, 2006; Buskens 2002; Morse *et* al, 2002; van der Mescht 2002; Gillham, 2000; Ashworth 1997b; Schutz 1994). This is best done if the researcher is in the situation and not merely conducting interviews about the situation (Patton, 2002). The researcher must be able to bring all of his/her experiences, feelings and problems relating to the research into the research, since the "being" of the researcher is part of the research (McNiff, 2008; Jacobson *et* al, 2007; Bergman & Coxon, 2005; Shank & Villella, 2004; Buskens, 2002; Patton, 2002; Schutz, 1994). This requires a lot of the researcher in terms of being competent and empathetic (Buskens, 2002; Patton, 2002). It means that I must explain my 'being' as a researcher.

I am a qualified biology teacher who had to stop teaching in 1994 for personal reasons. I did not want to lose contact with schools, and I took up a part-time post originally as a laboratory assistant at a former Model C school. Model C schools were white schools under the Apartheid Regime and thus received more funding from the State. This school had all the equipment necessary for the prescribed practical work, and a substantial budget for new equipment and replacement of damaged equipment. The post was converted to laboratory manager and resource developer. In this post I had to coordinate the practical work for the four biology teachers who taught from Grade 8 to Grade 12, and decide which practicals were done by the learners themselves and which were done as demonstrations. I also had to produce workbooks for Grades 10 to 12, with worksheets to cover the syllabus.

I worked from the backroom of one of the laboratories and I had perforce to walk through the classroom to get to the other laboratory and to consult other teachers. This meant that I became 'invisible' because the learners were so used to my coming and going that they did not notice me anymore. It also meant that I was able to observe how lessons were taught and what approaches were used by all four biology teachers and by other teachers who occasionally used the laboratory as a classroom.

While in this post I completed my Masters degree on the topic of the implementation of Outcomes-based Education (OBE). This required classroom observations as well.

After ten years at the school I left to become a research assistant at the University of the Western Cape. In this capacity I was involved in the Advanced Certificate in Education (ACE) programme, which enables full-time teachers to up-grade their teaching qualifications. Part of the programme included observation of lessons taught by the ACE students. I observed and reported on natural science and life science lessons for the ACE lecturers.

With this background I was able to evaluate the quality of the lessons I observed for this research.

4.7 Ethical considerations

The Western Cape Department of Education (WCED) was approached for permission to do the research in schools in the Western Cape. Permission was granted, and a copy the letter is found in Appendix A. Ethical clearance for the study was granted by the University Senate Research Committee.

Most researchers give assurance of confidentiality and anonymity and describe the intended use of the data. The time required for participation and the non-interfering, non-judgemental research role is explained (McMillan & Schumacher, 2001). Teachers taking part signed a consent form (Appendix D), which state that they participate voluntarily and that they can withdraw from the study at any time. Respect for the individual underlies the need for confidentiality (Hemmings, 2006; Easter, Davis & Henderson, 2004; Pritchard, 2002). This respect for persons was maintained since I am well aware of the difficulties teachers face every day, and value their work. Easter *et al* (2004) also note that confidentiality is more important where data is sensitive. No data collected in this study was what could be called sensitive. Learners and students were allowed to use pseudonyms if they preferred.

Some authors question the need for confidentiality and believe that it comes from positivist biomedical research (Yu, 2008; Jacobson *et al*, 2007). Yu, (2008) and Jacobson *et al* (2007) go so far as to say that confidentiality might deprive marginalised people of their voice, and Yu (2008) points out that the "thick description" required for qualitative research often makes identification of the respondents easy. The schools involved in this research were not unusual in any way, and the description given could apply to any number of different schools that I have visited, therefore I do not think that others would be able to identify the schools.

In quantitative research the relationship between the researcher and the respondents can be an unequal power relationship (Jacobson, *et al*, 2007; Buskens, 2002), but in qualitative research that relationship tends to be a relationship between equals (Jacobson *et al*, 2007; Buskens, 2002; Ashworth, 1997b).

Chapter 5 focuses on the presentation of the results and discussion of the results of the primary school data.

CHAPTER 5: PRIMARY SCHOOL RESULTS AND DISCUSSION

5.1 Introduction

This chapter describes the primary school studied and reports on the classroom observations. While primary school B was a State school which served the "Coloured" community, it was not a typical State school. It was a Roman Catholic school funded by the state and owned by a sector of the Roman Catholic Church. It was a large school with 1 200 learners. The teacher establishment was comprised of thirty-four teachers, and eight were employed by the School Governing Body.

As explained in Chapter 4 section 4.5, the acting principal was not in favour of having a researcher in the classrooms to observe lessons, but had been told that since permission had been granted he would have to allow me to observe classes. As a result it was extremely difficult to arrange for what I needed to do. I had originally asked to observe six lessons for each grade from Grade 4 to Grade 7, and was told that I could have four. When I arrived at the school I found that four meant four lessons, i.e. one in each grade. I negotiated to observe three lessons with the Grade 5 teacher but was unable to do so with any others. It eventually became apparent that the administration of the misconception test would not be possible. Teachers were polite but not interested in having me in their classrooms. Since this study entailed working closely with the teachers whose classes were being observed, it was simply not possible to carry on, and it was too late in the study to arrange for another primary school.

5.2 Background

Since asking questions elicited a negative response I was not able to find out much about the school. The only information I was able to obtain came from what I observed and the few answers that I did get from the secretary. The school appeared to serve a mixed community of middle-class and working class learners. There were children who had lunch provided each day, but there did not appear to be many of them. The feeder school on the property prepared Grade R learners. Since then, the primary school has incorporated the Grade R classrooms.

5.2.1 School facilities

There was a large asphalted playground flanked by classroom blocks. The playground was clean; there was no rubbish lying around. There were no sports fields except a large grassy "rugby" field. The school had a library but, according to one of the teachers, they were in the process of upgrading the library so it was not in use at the time of my classroom observations.

None of the classrooms in which I observed classes had overhead projectors, smart boards or any form of technology that I could see. All teachers used the blackboard. One teacher told me that she had difficulty finding pictures to illustrate ecological concepts. All teachers had textbooks from which to work, and there appeared to be no restrictions on photocopying material.

The classrooms were large and accommodated classes of 45 comfortably. There were posters and pictures on the bulletin boards and the rooms looked cheerful and inviting.

There was no school hall, so assemblies were held on the playground. This meant that they had to be held later in the day in winter because the asphalt was damp in the mornings. Each class filed out of its classroom in an orderly manner, with each child carrying his/her carpet square to sit on, and they organised themselves in their appointed places. When it rained there was no assembly.

5.2.2 Leadership and management

The acting principal informed me that the former principal was on sabbatical and would in all likelihood not return to the school. The acting principal was the second acting principal for the year, so it was understandable that he did not welcome having a researcher in the classrooms.

Principals were under pressure in 2010 because the World Cup Soccer hosted in South Africa (from 11 June 2010 to 11 July 2010) had resulted in longer school holidays. Learners could attend matches and school time was lost because of longer holidays. This might account for the general attitude that it was a nuisance to have a researcher in the school. A new Director General of the WCED had been appointed and had stated clearly that her emphasis would be on reading, writing, calculating, and that time spent on teaching and learning was the biggest problem in Western Cape schools (DBE Media Release 1 November, 2009). This might have added to the pressure on principals to see that teaching time was not disturbed.

A member of the School Governing Body (SGB) told me that the SGB was active and useful to the school. I did not get any information about the school from the principal.

5.2.3 Teachers

These teachers were qualified teachers. The Grade 7 teacher said that she had been trained to teach English but had been thrown in the deep end and was now teaching all Grade 7 Natural Science. The Grade 6 teacher had a B Ed honours degree from the University of the Western Cape. I do not know the specific qualification of the Grade 5 teacher.

5.2.4 The learners

It was immediately evident that these learners were well-disciplined, polite and confident. When I first entered the school ground at break time I was greeted politely by several learners. Learners were playing energetically all over the playground. All learners were neatly dressed in uniform. In the classes learners were clearly used to being expected to answer questions and to think about the answers they gave. When given work to do they were quiet and appeared self-directed in their work. At no time did I hear a teacher raise his/her voice to control a class.

5.3 Results of classroom observations

Since I was only allowed to observe a total of six lessons, no definitive conclusions can be drawn from these observations. Objections can be made that this was a "one shot" observation, and that it was not sustained to the point of data saturation. While that criticism is justified, the fact remains that I was not allowed to do more observations and had to use what was given to me. This case actually serves to illustrate the problems encountered in qualitative research. The observations did however serve to illustrate some of the difficulties in getting abstract concepts across to young learners.

Table 5.1 Summary of classroom observations, Grades 5 to 7

	GRADE 5	GRADE 6	GRADE 7
Class Size	± 45 learners	± 45 learners	± 45 learners
Technology Available	No technology available just chalkboard and chalk	No technology available just chalkboard and chalk	No technology available just chalkboard and chalk
Bulletin Boards	Charts and posters and pictures	Charts and posters and pictures	Charts and posters and pictures
Seating	Desks arranged in groups	Desks arranged in rows	Desks arranged in groups
Problems experienced	Difficulty finding enough pictures for the whole class to have pictures.	No visible problems and the teacher did not mention any	Finding good sources of information (textbooks are inadequate) and finding useful pictures
Topics taught	Lesson 1 Living & non-living things Lesson 2 Habitat & plants Lesson 3 Food chains	Ecosystems and biodiversity	Classification
Issues raised	None	None	None
Teaching strategies used	Question–and-answer worksheet Took class outside Children constructed food chains from pictures cut from books and magazines	Question-and-answer Took class outside	Question–and-answer Group classified organisms in picture on their own Group used a proper key to classify organisms
Teacher	D	E	F

5.3.1 Grade 4 (± 9 years old)

The lesson observed in Grade 4 was a mathematics lesson because, although I had specifically asked for Natural Science lessons, the principal had ignored my request and that was the only Grade 4 lesson I was allowed to observe. The teacher (Teacher G) allowed me to look at all her textbooks and the work schedules for science. In the short time I had to look at these learning materials I noted several inaccuracies. For example, the food chain was given with an arrow from the sun to the leaf with a ladybird on it, then an arrow to the mouse, then to the snake, to the eagle and from the eagle back to the sun. Ladybirds do not eat leaves and mice do not eat ladybirds. There is also the fact that nothing from the food chain returns to the sun. This picture could convey the misconception that all beetles are herbivores, that mice eat any plants and beetles, and that energy cycles through the food chain. Ladybirds are very easily recognised and that is probably why they were used as an example, but one would expect textbook authors to have some knowledge of the subject they are writing about. The quality of learning materials produced is poor. These learning materials were produced locally by a commercial firm and I was told that they were popular in schools. Nussbaum (1998: 175) comments that

> All too many textbooks which we have seen are based on content analysis and on the attempt to sequence materials *logically*. We have not found many textbooks which reflect an awareness of the various levels of cognitive demands presented by the material and/or of the cognitive difficulties faced by the students.

While this lesson was a mathematics lesson I was nevertheless able to see that the teacher used teacher-centred teaching. She used group work but merely for convenience. She did not allow pupils to discuss their problems with one another, and insisted on a quiet classroom.

5.4 Discussion

The Natural Science lessons observed will be discussed by Grade level. Three lessons were observed in the Grade 5 classroom and one each in Grades 6 and 7.

5.4.1 Grade 5 (± 10 years old)

When using the question-and-answer technique to determine the learners' prior knowledge, Teacher D waited for and expected answers to her questions, and learners knew that answers were expected. During the discussion of what humans need in order to survive one of the learners suggested that humans need energy, but Teacher D rejected this answer and thus missed linking it to respiration. No one mentioned oxygen as being necessary for humans.

Teacher D took the class outside to look at plants. The class was given a brief description of photosynthesis. Here it was apparent that they were having difficulty with the concept of a gas and in the end the teacher settled for "part of the air". This difficulty with abstract concepts can be expected from Grade 5 children because they are still in the concrete operational phase of development (Shayer & Adey, 1981). Grade 5 children range from 10 to maybe 12 years old. According to Séré (1993) children of the age of 11 have an idea of air as related to wind, but do not really understand what the properties of air are, and when one speaks of 'gas' they think of gas in lighters and stoves. They do not understand that air is made up of gases. Initially most children up to the age of 14 tend to believe that air is continuous, that is not made up of particles, but they are beginning to accept that there could be another view (Nussbaum, 1993). With this in mind it is can be seen that it is difficult to explain concepts like photosynthesis and respiration to this age group.

Another problem was the introduction of the term "glucose". None of the learners had ever heard of glucose, and the only way to get them to understand was to say that it is a sugar, which of course could lead them to think that what they know of as sugar is glucose. While Arons (1983) points out that it is possible to develop pupils' intellects beyond the concrete operational level, this would require a lot of practice and experience with abstract modes of reasoning. In an ordinary large Grade 5 class, with a teacher who has not specialised in science teaching, it is unreasonable to expect direct attempts to increase the abstract reasoning ability of the class. The question then remains, "How can one teach a Grade 5 child abstract concepts?" This will be discussed later in this chapter.

Teacher D was prepared to take the class outside, and I was glad to have been there when she did so because at one point she said to a child eating a leaf he had picked, "It's okay. It is green. It's healthy." Just next to that particular tree was a *Nerium oleander* which is extremely poisonous. This incident illustrates the lack of understanding of basic ecology. Teacher D needed to remain close to the textbook in order to be sure that what she was teaching was correct. Her own level of bioliteracy was a little beyond Uno & Bybee's (1994) functional level, but she had not reached the structural level yet. She could define terms and understood them, but she did not understand the major conceptual schemes of biology (structural level). There was no question of going beyond to action, as Hodson (2003) believes necessary.

5.4.2 Grade 6 (± 11 years old)

Teacher E unfortunately told the class, "Plants breathe in carbon dioxide and they breathe out oxygen" while discussing the characteristics of living things. It was meant as an analogy, but the learners will remember that statement and, as we will see in Chapter 7, some university students still hold that misconception.

The learners proved to be very observant, and came up with a complete food chain from what they had observed outside on the open ground behind the classrooms. When asked what the non-living things that influence the living organisms are, they came up with soil, rain, and the shadow cast by the building.

Teacher E was not fully conversant with animal classification and classified a frog as a reptile. She used the categories: reptiles, mammals, wild animals, and insects. The reasoning behind this classification was not clear. Teacher E appeared comfortable teaching ecology, but the classification system she used indicated that she did not have a good understanding of biology. The category "Wild Animals" was far too vague to have any scientific value. It is however impossible to draw conclusions from a single lesson. According to Uno & Bybee's (1994) levels of bioliteracy, the Grade 6 teacher in the lesson observed, like Teacher D in Grade 5, appeared to be a little beyond functional bioliteracy but appeared not to have reached structural bioliteracy. Without bioliteracy or scientific literacy, it is much easier for politicians or advertisements to make unsubstantiated claims and have the public accept these claims (Jeevanantham, 2005; Arons, 1983). Scientifically literate persons have more freedom in deciding for themselves how they choose to act (Jeevanantham, 2005; Roth 2003). A teacher who is not bioliterate cannot produce bioliterate learners.

5.4.3 Grade 7 (± 12 years old)

Teacher F allowed the learners to classify organisms using their own criteria, so that they had to look at the pictures given to be aware of characteristics. Only then did Teacher F introduce a scientific classification using a key. The learners enjoyed using the key and quickly sorted out various classes of invertebrates. It was an interesting and effective lesson, which was able to give the learners scientifically accurate information.

Despite admitting that she was not qualified to teach Natural Science, Teacher F enjoyed the subject and read widely. She was confident about her teaching because she had made sure that she understood the concepts involved. She acknowledged that it took a tremendous amount of work but said that she found it rewarding. Teacher F read widely and was interested in the subject. It is possible that she would have reached the multidimensional level of Uno and Bybee's (1994) level of bioliteracy. One lesson does not allow for a firm classification. She showed a broader, more interconnected understanding of biology than did the other two teachers.

The research in the primary school was thus what Eisner (2005:92) described when he said, "We conduct educational commando raids to get the data and to get out". He warns that what we get in such a short time is not a true picture of what happens in schools. Because of my prior experience observing lessons in a range of primary schools for the ACE course, I am confident that the picture was not distorted. There was also the fact that the teachers made no attempts to disguise any problems but commented freely about them, such as the difficulty finding textbooks that cover the work adequately and are interesting. The Grades 5 and 7 teachers admitted freely that they felt intimidated by ecology but nevertheless enjoyed it.

5.4.4 Can abstract concepts be taught in primary school?

The fact that all the teachers observed actually expected learners to give well-thought out-answers and would challenge any careless answers indicates that these teachers try to get learners to think about what they are learning. Not only is it possible but it is essential to teach abstract science concepts in primary school (Venville & Donovan, 2007; Egan, 2005; Peacock, 2004; Eshach, 2003; Arons, 1983; Novak, 1977). Children enjoy collecting things, observing natural things, and ordering them. They have a sense of wonder that motivates them to learn (Egan, 2005; Eshach & Fried, 2005). As Egan (1997) points out, young children are accepted as being "concrete" thinkers, but the development of language involves dealing with abstractions. He explains that if they could not think in abstract concepts they would not understand stories like Robin Hood and the Sheriff of Nottingham, or Luke Skywalker and Darth Vader. Children may not be able to define the concepts or even explain them but they understand them – otherwise they would not enjoy such stories. Egan (1997) believes that the idea that young children are incapable of understanding abstractions has led to an intellectually impoverished classroom. Over-emphasis on "active manipulation" undermines the child's ability to grasp meanings in other ways (Egan, 1997).

> I think the practical activity is certainly useful, but it can best support meaningful learning in a context of powerful abstractions; it is within the abstract context that the concrete content makes sense. (Egan, 1997:52).

According to Egan (2005), it is essential in teaching that we connect with students' imaginations if we want them to be successful learners. Imagination is the centre of education. It is tied to emotions in complex ways. "Imagination can be the main workhorse of effective learning if we yoke it to education's central tasks" (Egan, 2005: xii). Egan (1997 & 2005) believes that our understanding of the world we live in develops through five distinctive kinds of understanding in a specific sequence: Somatic, Mythic, Romantic, Philosophic and Ironic Understandings. Each kind of understanding results in the development of specific intellectual tools acquired from the society in which we grow up. Both Egan (1997 & 2005) and Vygotsky (1979) understand intellectual development to be in terms of cognitive tools, like language, and not in terms of psychological processes or of what knowledge we accumulate.

Each understanding thus provides us with a set of cognitive tools, which in turn help us to acquire more cognitive tools. Thus Somatic Understanding is the understanding of what we are capable of in the world, given the bodies we have. These understandings do not disappear when the next appears. Each understanding integrates into the next and is thus available to use when needed, but a little of the understanding is lost in the process of integration. Somatic Understanding is the understanding we work with from birth to about 2 years of age, when the development of language enables the development of other cognitive tools and we move on to Mythic Understanding, and so on. Below is a summary of the Understandings relevant to school-going children, and the cognitive tools that are developed with each type of understanding (Egan, 1997).

Table 5.2 Summary of Egan's Understandings, their accompanying Cognitive Tools, and the Phase of School to which they apply.

FOUNDATION PHASE (±6 – 8 yrs)	**INTERMEDIATE PHASE** (±9 – 11 yrs) **& SENIOR PHASE** (±12 – 14 yrs)	**FET PHASE** (±15 – 18)
Mythic Understanding **± 2 to ± 8 years of age**	**Romantic Understanding** **± 9 to ± 15 years of age**	**Theoretic Understanding** **± 16 to early 20s**
COGNITIVE TOOLS	**COGNITIVE TOOLS**	**COGNITIVE TOOLS**
❖ Story ❖ Metaphor ❖ Binary Opposites ❖ Rhyme, Rhythm & Pattern ❖ Jokes and Humour ❖ Mental Imagery ❖ Gossip ❖ Play ❖ Mystery ❖ Embryonic tools of Literacy	❖ Sense of Reality ❖ Extremes of Experience & Limits of Reality ❖ Association with Heroes ❖ Sense of Wonder ❖ Collections and Hobbies ❖ Knowledge & Human Meaning ❖ Narrative Understanding ❖ Capacity for Revolt & Idealism ❖ Changing Context ❖ The Literate Eye ❖ Embryonic tools of theoretic thinking	❖ The Sense of Abstract Reality ❖ The Sense of Agency ❖ Grasp of General Ideas & Their Anomalies ❖ The Search for Authority and Truth ❖ Meta-narrative Understanding

Teachers should harness these cognitive tools to enhance the learners' learning. Thus in the Foundation Phase science can be taught using stories and metaphors, and using music, rhymes and rhythm to assist in remembering. All parents know how much children enjoy fantasy. Young children enjoy finding 'binary opposites' such as hot/cold, knowledge/ignorance, male/female, which are actually abstractions. Because it is possible that these lead to stereotypes, teachers need to draw attention to stereotypes and show the consequences of such stereotypes. Binary opposites actually provide a tool for organising the world for the child, and the child will gradually become aware that binary opposites usually exist on a continuum. Jokes serve to show how language can be used and how it occasionally has double meanings. Egan (2005) has an outline of a lesson on air, using this approach to teaching children abstract concepts.

Vygotsky (1979) argues that if we wish to determine the relationship between learning and development, we first need to determine the actual developmental level of the child by looking at what he/she can accomplish. This is usually evaluated through testing. According to Vygotsky (1979), we mistakenly use these test results to maintain that this is all the child is capable of. We ignore the fact that with a little help the child can achieve at a much higher level than what he/she can achieve on his/her own. He defines the difference between what a child can achieve on his/her own and what he/she can achieve with a little help from an adult or more knowledgeable peer, as the zone of proximal development (ZPD).

> The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers is the zone of proximal development. (Vygotsky, 1979:85).

This ZPD forecasts future mental development, while actual development level explains what is already there. A child can only imitate that which is within its developmental level, and Vygotsky (1979:89) believes that "The only 'good' learning is that which is in advance of development". Working within the child's ZPD, an adult can mediate a child's learning and thus help him/her to a higher developmental level. According to Karpov (2003:46) "Mediation is the process of equipping children with mental tools…". All human mental processes take place with the aid of psychological tools, e.g. language, signs, and symbols – all of which are invented by humans and passed from adult to child. He explains it as follows: an adult and a child work together on an activity, during which the adult provides psychological tools to the child (verbal knowledge and relevant procedures) which allow the child to solve specific problems. In the beginning the child relies on the adult but the adult gradually encourages the child to take responsibility for the use of the tools, thus the child's activity becomes mediated by internal tools.

Novak (1977) and his team worked with first and second-grade learners, using an audio-tutorial programme of lessons they had developed in science. They found that at least a quarter of the group of eight-year old learners could use formal reasoning according to Piagetian criteria. In contrast to this we have the examples listed above, and Eyster & Tashiro's (1997) study that found that 16 to 18-year olds found nutrients, chemicals and atoms too abstract – they could manipulate pictures in their minds but not abstractions. Capon & Kuhn (1979) found that not all adults are capable of formal reasoning. Shoppers in their study did not know how to compare unit prices of two different brands. Arons (1983) states that research in cognitive development has shown that only 25% of college students have developed the ability to reason in the abstract. Fifty percent of students use predominantly concrete reasoning; the rest are in the process of achieving abstract reasoning, and are sometimes successful and sometimes still reason at a concrete level. How do we reconcile these findings with those of Novak and his team?

The child's relevant past experience and the quality of the instructional programme can explain the difference (Bers & Portsmore, 2005; Novak 1977; Novak, 1971). Novak (1977) notes that children and adults have "tremendously more learning capability" than suggested by their performance at school or work. Because of the effect of the instructional programme on learning, Novak and his team designed their audio-tutorial lessons so that there would be no input from teachers. Each of the lessons took a hundred hours of staff time to develop, test and polish. The lessons were designed mainly for Grades 1 & 2, but they found that even 5^{th} and 6^{th} graders enjoyed using them. The lessons were administered to a group of 191 pupils. Forty-eight pupils taught by the same teacher acted as a control and did not use the audio-tutorials (Novak, 1998). Testing showed that by Grade 12 the group using the tapes was found to have fewer misconceptions than the group taught by the teacher. Those learners who had used the tapes increased their understanding of science because they were able to use the anchoring concepts they had learned from the tapes to help understand new knowledge presented later. It is thus clear that

> when powerful anchoring concepts are learned early in an educational program …, they should provide a foundation for facilitation of later learning (Novak, 1998:15).

Primary school teachers are expected to be able to teach all academic fields (Crowther, Cannon & Hodges, 2005). Another of the problems with science teaching in primary school is that primary school teachers do not have sufficient science in their training (Bers & Portsmore, 2005; Tosun, 2000; Novak, 1998; Wenner, 1993). Tosun (2000) warns that the remedy for this is not simply having them take more science courses, because the teaching in the science departments is such that it might have a negative impact on the teachers. It would thus appear that there is little communication between science departments and education departments at universities. While there is a substantial body of research on education, biologists have not read it, and it may be inaccessible to them because of the language used and the unfamiliar qualitative methods (Orsmond, 2007). As Roth (2003) points out, scientists have claimed a complete lack of interest in what and how science is taught. Novak (1998:5) noted that his graduate courses in Education were "trivial or borderline nonsense." Thus it appears that education faculties do not provide sufficient science, and science faculties do not know enough about how to apply education principles.

Not all the blame rests with the teachers. In South Africa there are too many children who are virtually raising themselves because of HIV/AIDS and poor economic conditions (Bloch, 2009). These children are unlikely to have been exposed to the necessary preparation for schooling, and will thus not have relevant experience on which to draw when learning science. Once again we return to the problem of poverty and its impact on learning.

In the next chapter the high school results will be discussed, and misconceptions revealed by the questionnaire will be noted and their possible origin determined.

CHAPTER 6: HIGH SCHOOL RESULTS AND DISCUSSION

6.1 Introduction and background

This chapter will be discussed in two parts. The first part will describe the high school studied, and then the results of the misconceptions questionnaire in Grades 8 to 11 will be reported and discussed in relation to the tables reporting the results. The second part will report on and discuss the results of the classroom observations.

This "thick description" of the school is necessary to put the results in context and to allow for naturalistic generalisations (Freeman *et al*, 2007). Information about the school came mainly from the two deputy principals, since the principal was very busy. He did answer my initial questions.

High School A was an ordinary state school, which was a former House of Representatives school for "coloured" people under the apartheid regime. This simply means that it was dependent on the State for its resources, and was not funded as well as the white schools were. It had an active School Governing Body (SGB).

The school term in which the section on Environmental Studies was taught was not the best time to observe classes. The principal made it clear to me that no testing or interviewing would be allowed in class time, as there were only 23 days of contact time in that term because of the 2010 Soccer World Cup which started on 11 June and ended 11 July . Additional pressure came from the emphasis placed on time-on-task by the Director General of the Western Cape Education Department, who made it clear that no outside interference would be tolerated in schools (Media Release 1 November, 2009, downloaded from the DBE website) (?): http://wced.school.za/comms/press/2009/100_1nov.html.

I was allowed to observe classes but not to use class time for anything else. The principal arranged for the misconceptions test to be done in an Administration period on a Tuesday morning before classes.

6.2 The school

The school was situated in a middle class area in a predominantly "coloured" suburb. It had a small area in front of the school with trees and shrubs. The rest of the grounds had either paving or uncared-for lawn. The lawn was mowed regularly but not watered or weeded regularly and was thus not lush and green, but served to control dust. There were rows of trees planted along the perimeter of the grounds. The school grounds were neat and clean.

While there was space for sports fields, there were no demarcated sports fields. The deputy principal told me that this was because the construction and maintenance of sports fields was beyond the reach of the school's budget. He commented that sports fields would have enabled the school to keep learners off the streets over weekends.

The school had attempted to focus on the academic side of education, and each learner had a textbook which belonged to the school and was returned to the school at the end of the year. When I asked how the school ensured that textbooks were returned I was told that if learners did not return their textbooks they would not be issued with a textbook each at the beginning of the next year. Despite this precaution the school still lost anywhere from 10 to 50% of their textbooks each year.

There was a Khanya computer laboratory. The Khanya Laboratories project is an initiative coordinated by the Western Cape Education Department, established in 2001. It coordinates the donations of business and private NGOs, and attempts to provide all disadvantaged schools with computer laboratories so that the shortage of skilled teachers can be mitigated. The reasoning behind establishing a computer laboratory rather than a library was that learners could then access information on the Internet. It had become evident that there were too many learners who were not computer literate for this approach to work. Unfortunately the school had neither space nor funding for a library.

The two science laboratories that I saw were not very well-equipped, and were too small for the large Grade 8 classes of 50 or more learners. The school has only six microscopes, so it was difficult to ensure that learners developed the skill of using the microscope. The Grade 8 teacher whose classes I observed, Mr A, described how they covered the practical work for Grade 8. Half of the class would go to the laboratory, where Mrs C would do the practical work with them, while Mr A supervised the remainder of the class in his classroom. On the same day of the next cycle the other half would go to the laboratory so that all got the work done. The timetable thus had to be organised so that Mrs C had a free period for each of the Grade 8 classes, of which there were four. This arrangement had deprived Mrs C of her free periods. It was obviously not an ideal situation, but there was no other way to cope with the large numbers of learners. No practical work was done with Grade 8 during the time that I was observing lessons.

6.2.1 Leadership and management

Teacher A showed me the school's advanced planner for the year. Every important date was listed right at the beginning of the year. It was clear that the management team was well-organised.

I asked one of the deputy principals if the School Governing Body was active and useful to the school, and he assured me that it was very supportive. The fact that Teacher A's salary was paid by the Governing Body was an indication of the type of support that was given by the Governing Body.

6.2.2 Teachers

Table 6.1 Teacher qualifications and teaching loads

TEACHER	TEACHER A	TEACHER B	TEACHER C
Qualifications	Qualified Maths teacher teaching Natural Science, Life orientation and Geography. Admitted that he struggled with ecology.	No information.	Qualified to teach up to Grade 10 but teaching up to Grade 12. Felt that the WCED should give training in how to teach ecology.
Teaching load	30 of the 42 periods per cycle	34 of the 42 periods.	36 of the 42 periods.
Classes taught	Grade 8	Grades 9 & 10	Grades 11 & 12
Practical work	Class too large to fit into lab for practical work. Teacher C did practical work with half the class at a time	Classes too large to do practical work – demonstrations were done.	Helped do practical work with Grade 8, this meant that she often did not get any free periods in a cycle.
General Comment	Governing Body post – not paid much, had to do extra work to earn extra money.	Hesitant to have me in his class but eventually relented.	Wanted to up-grade her qualifications but the ACE course did not give content knowledge.
Extra-mural duties	None required	None required	None required

ACE = Advanced Certificate in Education. It is a part-time course to help teachers upgrade their qualifications.

WCED = Western Cape Education Department

6.2.3 Learner background

All learners wore school uniforms. The school had a fairly mixed group of 1200 learners. There were many middle-class learners from the surrounding area but there were also learners who needed lunches provided. The school had a feeding scheme, and at the first recess the school tea lady would hand out sandwiches that she had prepared to specific learners. She would go to a set point on the school ground and learners would come and get sandwiches. I was not told how many learners required lunches.

6.3 Results of misconceptions questionnaire Grades 8 to 11

When told that I was looking at misconceptions in ecology, a colleague asked if I was actually finding misconceptions or just "no conception". The results of the questionnaires support his assertion that the learners have "no conception". I was not able to interview learners, as there was no time during the school day and the principal did not allow me to use the learners' break time for my research.

The answers to the questionnaire highlighted a common problem in schools, that of copying. For each question there were several learners who had identical answers which often did not really relate to the statement. The tables below give a summary of the results. The Grade 8 & 9 questionnaire had only eight questions.

Table 6.2 Percentage of valid answers per question for Grade 8 & Grade 9 learners

Question		GRADE 8 (43 learners)	GRADE 9 (44 learners)
1	Plants use oxygen.	7	13.6
2	A cow is a producer within a food chain because it produces milk and meat which we eat.	0	0
3	A dragonfly is not an animal.	16.3	22.7
4	If plants and seaweeds disappeared from the earth and sea, I would die.	32.6	70.5
5	Plants get most of their food from the soil.	18.6	0
6	There are no producers in water.	0	18.2
7	Dinosaurs did exist.	51.2	68.2
8	All that plants need is light, water and minerals from the soil.	9.3	0

From Table 6.2 it is evident that there are a few learners who know that plants need oxygen. None of the learners know what a producer is. The Grade 9 learners are slightly more aware of how organisms are classified. Grade 9 learners appear to know that we need plants but do not remember that plants make their own food and do not get it from the soil. Question 7 is the only one that has been answered adequately. Dinosaurs must have caught the imagination of the learners.

Table 6.3 Percentage of valid answers per question for Grade 10 and Grade 11 learners

Question	GRADE 10 (25 learners)	GRADE 11 (32 learners)
1 Respiration only takes place in animals; plants have photosynthesis instead of respiration.	12	3.1
2 Plants need a suitable source of nitrogen otherwise they will die.	28	0
3 A cow is a producer within a food chain because it produces milk and meat which we eat.	12	31.2
4 If plants, seaweeds and phytoplankton disappeared from the earth and sea I would die.	56	71.9
5 A dragonfly is not an animal.	16	43.8
6 Decomposers release some energy that is cycled back to plants.	8	0
7 Soil is one of the biotic components of the ecosystem because it gives mineral salts and water to plants.	4	28.1
8 An organism may occupy more than one trophic level in a food web.	12	6.3
9 Producers do not occur in water.	24	34.4
10 Energy is lost at each trophic level of the food chain.	4	28.1

From Table 6.3 we see that there was very little understanding of the relationship between photosynthesis and respiration, even in Grade 11. The nitrogen cycle, Question 2, was covered in Grade 10 but it was disconcerting to notice that the Grade 11 class had no knowledge of why nitrogen is important to plants. Questions 3 and 9 revealed that learners did not understand the concept of "producer" in terms of Life Science. Only Question 4 was answered satisfactorily. Even there one would have expected a higher percentage of valid reasons in Grade 10. Learners were not conversant with the terms used in ecology. They could not distinguish between biotic and abiotic factors, nor did they know what a trophic level is.

6.3.1 Photosynthesis and respiration

Learners often held more than one misconception about photosynthesis and respiration. These misconceptions were found even in Grade 11, after photosynthesis and respiration had been carefully covered in Grade 10. Teacher B was very careful to point out the relationship between photosynthesis and respiration in one of the lessons I observed. Teacher B started out by asking questions about how the quantities of various elements were maintained in the system. He asked questions that led into the carbon cycle. Learners were given two pages illustrating the carbon cycle and the nitrogen cycle. He very clearly spelt out the relationship between photosynthesis and respiration and explained how both related to the carbon cycle.

Table 6.4 Grades 8 to 11 misconceptions about photosynthesis and respiration

MISCONCEPTION HELD	Percentage who hold the misconception			
	8 n=43	9 n=44	**10** n=25	**11** n=32
Do not recognise that plants need oxygen.	72.1	84.1	-	-
Plants do not respire.	-	-	28	43.8
Plants take in carbon dioxide and give off oxygen as their form of respiration.	16.3	38.6	20	12.5
We don't need plants.	16.3	15.6	12	18.8
Only humans use oxygen.	6.8	2.2	-	-
Respiration equated to breathing.	6.8	9.0	4	6.3
Only trees give us oxygen.	0	4.5	0	0

The high percentage of learners in Grades 8 and 9 who do not know that plants use oxygen indicates that they have no understanding of what respiration is, beyond taking in oxygen and giving off carbon dioxide in animals and humans.

6.3.2 Food chains

Peacock (2004) argues that "eco-literacy" for all learners is essential because the future of humanity depends on an understanding of ecology. An understanding of how food chains and food webs work is also necessary if we are to try to maintain what we have in terms of biodiversity.

Table 6.5 Grades 8 to 11 misconceptions about food chains & food webs

MISCONCEPTION HELD	**Percentage who have that misconception**			
	8 n=43	**9** n=44	**10** n = 25	**11** n=32
Any organism that provides food for another organism is a producer.	95.3	84.1	84	56.3
Plants get most of their food from the soil.	79.1	81.8	0	12.5
There are no producers in water.	20.1	38.6	4	-
Water treatment plants produce water.	11.6	0	-	-
Water is food.	11.6	0	-	-
Energy accumulates up the food chain.	-	-	40	9.3
Plants do not need nitrogen.	-	-	28	46.9
Decomposers release some energy that is cycled back to plants.	-	-	64	81.3

The only learners in Grades 8 and 9 who disagreed with the statement "A cow is a producer within the food chain because it produces milk and meat which we eat" were clearly vegetarian, as the following statement indicates: "Cow only produces milk and we only drink milk and not eat it." This statement was typical of the others who disagreed. As can be seen in the table above, the general understanding of "producer" was that any organism that provides food for another organism is a producer. This even applied to the Grade 11 class.

6.3.3 Classification

Learners need to be able to recognise that living organisms are grouped together on the basis of similarities and differences, and that this makes it easier to study living organisms and understand evolutionary relationships. Learners did give some evidence of being able to group organisms as seen in the table below. They knew what insects are, but many had misconceptions about what could be called an animal. The statement was "A dragonfly is not an animal".

Table 6.6 Grades 8 to 11 misconceptions about classification

MISCONCEPTION HELD	PERCENTAGE OF CLASS			
	GR 8 n=43	GR 9 n=44	GR 10 n=25	GR 11 n=32
Insects are not animals.	36	31	59.3	47
All animals can fly.	14	2	0	0
Animals are big so anything small cannot be an animal.	-	2	0	0

Some reasons given revealed that these learners did not know what dragonflies are, e.g. "Because a dragonfly is a lizzard and we do not need any part of a dragonfly for a food source" (a Grade 10 learner). Notice that the answer includes a reference to a food source. That was not mentioned at all in the statement. The following reason given illustrates the problems that teachers have teaching Life Science, "Because every creature that God made is an animal". Only one learner in Grade 11 did not know what a dragonfly is. "It is an animal cause it is something lives and breath like humans just that now adays we don't see them they are extinct from the earth." For the rest of the learners it became a question of whether or not an insect is an animal.

6.4 Discussion of test results

6.4.1 Photosynthesis and respiration

It would appear that the fact that photosynthesis is not dealt with in Grade 9 means that the learners have employed the process described by Tunnicliffe & Ueckert (2007:51): "The process is 'learn, test and dump' rather than learn, test, and build on the knowledge to learn additional concepts". This is true for Grade 11 learners as well. Photosynthesis is covered in Grade 10 but the Grade 11 class showed little understanding of the process of photosynthesis.

Even the Grade 8 textbook used by the school defined respiration without mention of oxygen, so that it was not necessary to give a separate definition of anaerobic respiration. The definition given was "**respiration** – chemical reactions that happen in cells to give organisms energy." (Ayerst, Dalton, Khumalo & Smith, 2006:37). The topic is not dealt with directly, and that definition was given as a footnote in Unit 2: Atmosphere and Weather. It was not repeated in the Glossary at the back of the book, though the term "teratogen", a substance or factor causing malformation of the embryo, was defined both as a footnote and in the glossary.

An analysis of the National Curriculum Statement Grades R – 9 for the Natural Sciences (DoE, 2002a) revealed that photosynthesis and respiration were not mentioned in any form for the Foundation Phase (Grades 1-3). Obviously the technical terms would be too difficult.

In the Intermediate Phase (Grades 4-6) the initial understanding of photosynthesis is set out clearly and adequately:

> <u>Life Processes and Healthy Living</u>
>
> - Green plants produce their own food and grow by using water and substances from the air and soil. Energy from light is needed to change these simple substances into food and plant material. Green plants are the only organisms that can produce food in their own bodies.
> - Living things need food for energy, to move, grow and to repair damage to their bodies ('tissues'). Animals including humans have digestive systems for getting nutrients from food. Humans need a balanced diet from certain groups of food to be healthy.
>
> <u>Interactions in Environments</u>
>
> - Animals cannot make their own food, and so some animals eat plants for food while some animals eat other animals. All animals ultimately depend on green plants for their food. (DoE, 2002a:62, 63.)

Unfortunately there is no similar understanding of the role of respiration. These statements do not indicate the importance of respiration at all. A careful reading of the chapter entitled "Core Knowledge and Concepts" yielded a small section dealing with respiration which was not named, while photosynthesis was named and clearly summarised.

CORE KNOWLEDGE AND CONCEPTS IN MATTER AND MATERIALS
Senior phase
Structure, Reactions and Changes of Materials

- The reaction of oxygen with food releases energy in the cells of living things. *(Links with Life and Living).* (DoE, 2002a:75)

Energy Transfers and Systems

- Examples of potential energy are … or in the food and the body of a living thing. (DoE, 2002a:67)

Life Processes and Healthy Living

- Green plants use energy from the sun, water and carbon dioxide from the air to make food by photosynthesis. This chemical reaction is central to the survival of all organisms living on earth.
- Animals, including humans, have a circulatory system which includes the heart, veins, arteries and capillaries, and which carries nutrients and oxygen to all parts of the body and removes waste products. Oxygen, which is provided by the breathing system, reacts with food substances to release energy. (DoE, 2002a:64)

Respiration is not named, although it would not be difficult to differentiate between respiration and breathing in Grades 7 to 9. The concept of respiration is no more complicated or difficult to understand than the concept of photosynthesis. One could start a discussion on respiration by relating it to breathing, then asking why we breathe and what happens to the oxygen we take in, and showing that plants also need to respire (Flores & Tovar, 2003). As can be expected, these Grade 8 and 9 learners did not have a basic understanding of the relationship between photosynthesis and respiration; in fact they did not know anything about respiration because they had never encountered it. It was covered in Grade 10 but no connections were made to the work done in Grade 11, therefore Grade 11 learners simply forgot about photosynthesis.

6.4.2 Energy flow and food chains

There were a few learners who recognised the fact that cows ate grass, but they did not appear to find this incompatible with the concept of a producer. Below is a response indicating that some learners at least know that cows eat grass.

> If there is no cows were will we get milk meat to eat and yes a cow is a producer within the food chain grass→ cow → milk → meat → me. (Grade 8 Learner).

The National Curriculum Statement (NCS) implies the concept of food chains in the following statement:

> ***Senior phase***
> Interactions in Environments
>
> - An ecosystem maintains numerous food webs and competition for food among different individuals and populations. South Africa has certain ecosystems which have exceptional biodiversity. All uses of these areas must be based on principles of sustainable development (DoE, 2002a:64).

This concept, while not directly used in the NCS, is used in the Senior Phase Work Schedules supplied by the Western Cape Education Department (WCED) for the Natural Sciences.

For Week 5 of Term 1 the following instruction is given:

> Briefly revise:
> - Adaptation
> - Biodiversity
> - Ecosystem
> - Food chain
> - Food pyramid (WCED:5)

Soil was regarded as providing food for plants. Because learners do not know what a producer is it is not surprising that there was no understanding of the question which stated that there were no producers in water. Even learners who disagreed with this statement did so for the wrong reasons e.g. "If we don't have food to eat we can live on water to survive and not to die." and "I disagree because there is no water producers." Obviously what happens out of school has a greater impact on the learners than what happens in school, as the following quote illustrates: "because producers is someone that makes films." This question also yielded other interesting misconceptions such as, "the government produces the water to people but we can also collect water at dams" and "there are a lot of producers in water like minnerall water". Even in Grades 10 and 11 there is still no understanding of what a producer is. The following reason was given for disagreeing, "Most things need water so it is an producer e.g. (cooldrinks plants)".

Many of the Grade 10 and Grade 11 learners did not know what a food chain is, as demonstrated by the following statement: "Some organisms eat the food chain to provide for them selfs". *Trophic level* is also a concept that they do not understand e.g. "We have different food webs not just the trophic level" and "An organism is a level of a food web chain that shows how it is done so more than one trophic level of occupy is nothing"(sic). This "sentence" also demonstrates their inability to communicate in writing.

Despite studying the Nitrogen Cycle in Grade 10, none of the learners demonstrated any understanding of why nitrogen is important for plants. The reasons given were vague and meaningless e.g. "Plants need certain things such as water, sunlight, and proper soil which could contain some nitrogen, in order for it to grow". In Grade 10 and 11 twenty-eight percent and forty-six percent of learners respectively believed that plants do not need nitrogen, e.g. "Plants do not need nitrogen they need oxygen".

6.4.3 Problems exposed by the questionnaire

The reasons given for agreeing or disagreeing with statements revealed problems that learners had with language. These problems included an inability to comprehend what they were reading, and there was also an inability to write clearly so that their meaning could be understood. All statements quoted are given exactly as written.

6.4.3.1 Comprehension of what they read

The first problem that became evident was that of learners being unable to read the questions with comprehension. This finding is supported by Bloch's (2009:64) statement, that only about 19% of our children "could do 'analytic' or 'critical' reading". After agreeing that a dragonfly is **not** an animal, a Grade 11 learner gave the following reason, "It is an animal but falls under the group of insect due to its being small". In Grade 8 close on 7% of the learners contradicted their agreement or disagreement with the reasons they gave, e.g. a learner agreed with the statement which said, "*A dragonfly is not an animal*", and gave as a reason, "It is a animal because it can fly". Another learner disagreed with the statement, then gave as a reason, "It is not an animal".

Lack of comprehension was also shown in the way simple statements were interpreted. For example, for the item which stated, "*There are no producers in water*" (Grades 8 & 9), or, "*Producers do not occur in water* "(Grades 10 & 11), they gave reasons which revealed that they did not understand the sentences. The following responses show the depth of the learners' lack of understanding. The Grade 8 learner agreed with the statement and gave as a reason, "Because water is not dirty but not dam water". Another, a Grade 9 learner, responded, "I disagree because water is a natural thing, no one can make water". In Grade 10, "Rain sometimes raises a sea level, which means that rain can/could be a producer for water". Grade 11, "Not many producing can take place though or under water and I can't think of any producers under water". These are just single examples from each grade. There were many other such examples.

Question 2 (Grades 10 and 11) stated, "*Plants need a suitable source of nitrogen otherwise they will die*". The following reason was given for agreeing: "If there is no water and soil and the sun the plants want be able to grow that is why they need sources".

Learners also confused words ending with "tion" with one another. Respiration, reproduction and production were often confused, and in the higher grades transpiration featured as well, e.g. "Respiration takes place in plants too. The uptake of water is respiration pull and that happen in a plant up taking water from the soil to the leaves", and, "Photosynthesis happens in plants this is when pollin is released from the plants into the air as for animals this cannot happen to it respirates", and "Only animals can give birth to live animals or in some kind of other form but plants do not give birth and that is where photosynthesis comes in". One can see that reproduction has somehow been confused with respiration.

According to Carlisle and Flemming (2003), children start learning complex words by discovering affixes and then attempting to discover the meaning that a particular affix gives to a word stem. In this case there is the suffix "tion", and the fact that "production" has "re" in front of it in "reproduction", which to the child must mean that they are somehow related. If the learners are not familiar with the full word or the morphemes that make up the word, then their morphological processing is incomplete and they are likely to get confused (Carlisle & Flemming, 2003). In this case, words like 'respiration', 'reproduction', and 'production' are not everyday words for most people, therefore learners are unlikely to be familiar with their meanings.

6.4.3.2 Ability to communicate in writing

This study was designed to investigate misconceptions held by learners and to attempt to find the origin of these misconceptions. A study of language was never intended to be part of this study and I do not claim to be a linguist, but the results obtained from the questionnaires necessitate some comment on the problem of language in schools. This study was done in the classes receiving Natural Science and Life Science instruction in English. Classes in Afrikaans were available, so one can assume that most in the class had English as a home language. The black learners in the classes would have had English as a second or third language. There were not many black learners in the any of the classes I observed. Basic literacy is necessary if scientific literacy is to be achieved.

As pointed out in section 6.4.3.1, the learners do not understand what they are reading. What I had not expected was the widespread inability to write in English. The only way to illustrate this problem is to quote widely from the responses to the "Please explain your choice" sections of the questionnaire. The answers reveal grammatical errors and lack of logic. The quotes are given as they were written, so the lack of punctuation is part of the problem.

Grades 8 and 9

- If it don't have oxygen and sun we will die and the plants so it need oxygen.
- A cow is a producer because it is meat and it gave us milk.
- Because they grow better and it's good for the inveremintion.
- Because it an incect it's not as big or something big like ther other things.
- All creatures that can talk is animals the reason why I say so is because God creatured butterflies, flies etc and they are all creatures.

Grades 10 and 11

- Respiration can take place in your body as well and plants consist of photosynthesis.
- The cow is not the producer because the grass and plant that the cow is the producer and if that wasn't there the cow would never have produced milk and meat.
- Animals will begin to get weaker, because some animals live off plants seaweed and some off those animals we eat most of the time us as humans will get weaker too because of animals that will die.
- Only humanly alive things consist of respiration. and plant's arent humanly alive/dont live like animals. because if we dont look after a plant it may die.
- If plants dont get enough of nitrogen nor photosynthesis they will die in order to grow.
- Plants do not always need nitrogen source otherwise how will plants be suitable in need.
- If cows weren't invented us humans wuld not be able to gather milk or meat from the cow.
- Whatever is releases to plants, in the cycle must come back so that it can make that certain cycle. Then plants will be able to give off carbondioxide.
- There are many sea creatures which produce us with food.

- Energy is not lost because it bolds up the other animals energy that had eaten and the animal that is eatens energy is lost which may cause it to die.
- A food chain would normally consist of: grass -> cow -> man. Man eat cow, cow eat grass fors the food chain to execits.
- Decomposers release a energy source of carbon that is taken in by plants that's reproduced through photosynthesis to oxygen.

One may feel that I have quoted too many examples, but these are but a few of the examples that could have been quoted. Teachers are expected to extract meaning from such statements and to grade these. Though language teaching should be infused in the teaching of any subject (Simmich-Dudgeon & Egbert, 2000), it must be remembered that teachers have specialised in a field and are not necessarily linguists who feel competent to correct grammatical and other mistakes.

South Africa has a problem with literacy and numeracy, as shown by the Annual National Assessments of 2011 which measured literacy and numeracy in Grade 3 and language and mathematics in Grade 6. In Grade 3 the average percentage scores for the entire South Africa were 35% for literacy and 28% for numeracy. In Grade 6 the average for South Africa was 28% in language and 30% in mathematics (Department of Basic Education, 2011).

The infusion of language teaching in the teaching of Life Science or Natural Science would require more teaching time (Carnine & Carnine, 2004) and smaller classes, because it would require more 'marking' and feedback (Nystrand & Graff, 2001) as the teacher would need to show the learner where he/she had used the language incorrectly. This means that the teacher would also need to be fluent in the language of instruction, and we know this is not the case in South Africa (Bloch, 2009). I feel that the obstacles to the infusion of language teaching in subject teaching are insurmountable, and therefore we need more research on how to overcome this problem.

If teachers were more secure in their teaching, it might be possible to integrate teaching English and Life Science by using the English teacher's expertise to correct language in Life Science reports and essays. This would only work if the English teacher could then use those assignments as part of his/her own continuous assessment portfolios. Otherwise it would merely serve to increase the English teacher's load. Carnine and Carnine (2004) suggest the following principles must be in place if teachers are to help learners read better, but these can be applied to writing as well:

- Training (professional development) for teachers in science and reading (language) instruction;
- Enough teaching time;
- Checking that teachers are really covering big ideas;
- Proper discipline at school so that it is a safe place;
- Good administrative leadership that helps select appropriate instructional materials and ensures their use.

When one looks at the level of bioliteracy as suggested by Uno & Bybee (1994), these learners have not fully reached nominal level because they cannot recognise biological terms, although they do know that biology deals with living organisms. The learners have reached Osborne's (2002) second level of general literacy because they can read, but without understanding. They can recite facts but they do not understand them.

6.5 Results of classroom observations

I had asked to observe at least six classes per grade, but was given six classes per teacher. One class was missed for Teacher A, because he clearly did not like being observed, and I decided that it was not productive for me to observe learners copy notes from the chalkboard when I knew that the teacher was feeling most uncomfortable. One class with Teacher C was missed because she was sick on one of the days scheduled for observation. A total of sixteen lessons were observed.

Because the term in which the classroom observations were done had only 23 contact days, there was a sense of pressure from the beginning. "We must finish the work for this term", was the constant refrain of teachers. This pressure resulted in lots of note-taking, with very little explanation of new work and concepts. The first week of the quarter had already been used to finish up the work that should have been done the previous quarter, thus demonstrating McComas' (2003) assertion that important topics in ecology are left to be done if there is time.

Table 6.7 Comparison of classroom conditions and teaching styles

	Teacher A	Teacher B	Teacher C
Class Size	45 to 52	35 to 50	30 to 40
Technology Available	No technology available just chalkboard and chalk.	Overhead Project & transparencies.	Overhead project had been in for repair since the previous year.
Bulletin Boards	Covered with newspaper to hide graffiti.	Charts and posters and learners posters displayed.	Charts and posters and learners posters displayed.
Seating	Desks both single & double. Some single desks seated 2 learners. Desks in rows.	Tables and stools many of the stools were broken. Tables in rows.	Tables and stools in rows.
Teaching strategies used	Chalk & talk with no real questioning. Notes written on chalkboard.	Chalk & talk with questions to involve learners. Notes given on OHP. Using the textbook to find information.	Question & answer to elicit what learners knew. Using the textbook to find information. Outdoor work looking at biodiversity. Practical work.
Problems experienced	Large classes with little room to move. Lack of resources. Textbook did not match the WCED work schedules.	Large classes with little room to move. Lack of resources. Insufficient space to do practical work.	Fairly large classes. Lack of resources.
Topics taught	Biodiversity (Grade 8).	Carbon cycle (Grade 10) Diseases caused by micro-organisms (Grade 9). Water cycle (Grade 10). Fynbos 2 lessons (Grade 10). Classification (Grade 10).	All lessons were Grade 11. Biodiversity 2 lessons. The Fern. Gymnosperms. Angiosperms.

6.6 Discussion of classroom observations

As can be seen from Table 6.7(above), Teacher A's classroom was bleak. There were no pictures and the bulletin boards were covered with newspaper to hide the graffiti. There was no evidence of any form of technology. He just had a chalkboard and chalk. His classroom was so crowded that doing any form of group work would have been difficult.

Teacher A freely admitted that he was a mathematics teacher, and did not know anything about Natural Science. He could not use any strategies to determine learners' prior knowledge. He relied on rote learning from notes written on the board. All classes observed followed the same pattern, with a brief introductory speech and then notes written on the board for the learners to copy into their notebooks. Grosser & de Waal (2008) point out that Outcomes-Based Education requires teachers to be mediators in the learning experience, and in order to do this teachers must be able to integrate knowledge and skills. They must be competent in their learning area. As a result of having restricted interaction with the learning materials, learners did not get any opportunity to build their own knowledge.

Teacher A had reached a functional level of bioliteracy (Uno & Bybee, 1994), in that he could define terms but did not really understand them, and had no understanding of major conceptual schemes in biology.

Teacher B was able to use questions to draw out the learners and to lead into the topic he planned to discuss in class. When he gave exercises to do from the textbook he used the time to check the learners' books. He also had learners read sections of the textbook and then discuss what they had read in their groups. Mashalaba and Sanders (2003) note that teachers in South Africa do not make adequate use of the textbook for activity-based lessons. Teacher B used the textbook effectively to get the learners to read. This is also an example of the infusion of reading into Life Science lessons.

Teacher B said that he would have loved to do practical work with the learners but even if he had had sufficient apparatus, he would not have had sufficient space for them to move about freely. He would have liked to take his classes on field trips but the logistics of taking at least 90 learners (he taught three Grade 10 classes) on an outing made it a formidable task. He told me that he was not allowed to ask another teacher to accompany him. He was expected to ask if any parents would accompany the class on the outing. An outing with the Grade 9 class would have been even more difficult, since there are 45 to 55 learners in each of the three classes that he taught.

Teacher B said that teachers need resources, like work sheets, that they can use without having to modify them. He told of how difficult it is to find anything in Afrikaans. He said he often found very useful diagrams with notes in English, but that he did not have the time to translate them. The Afrikaans learners are complaining that they are neglected because they also have difficulty finding information in Afrikaans.

Teacher B appeared to have reached a structural level of bioliteracy and might have reached the multidimensional level, but because he was reserved and did not want a researcher in his classroom, it was difficult to judge his level of bioliteracy. He certainly understood the subject, as was clear in his lessons.

Teacher C most clearly enjoyed her subject. She was enthusiastic about her classes and took them outside to look at the diversity of living things found on the school grounds. She was prepared to admit to not knowing all the answers, and would then encourage learners to look for an answer.

She had the learners look at the fern sporangia under the microscope. There were only six microscopes, so these were set up with wet mounts of fern sporangia, and the learners lined up to look. They were also given fern leaves to look at, while she used questions to probe their understanding. In the lesson on Angiosperms learners had to dissect the flowers they had been given, and then use the textbook to decide whether the flowers were monocotyledons or dicotyledons. She did not give them the characteristics of each group. They had to find them for themselves. According to Grosser and de Waal (2008), a mediator must be competent in his/her learning area.

Although Teacher C admitted that she was only trained to teach up to Grade 10, she was prepared to read to learn more and she worked hard to learn more in her subject. Grosser and de Waal (2008) speak of practical competence, which will enable a teacher to approach concepts in a relaxed fashion. Foundational competencies mean that the teacher must be able to teach the language of his/her learning area, and reflexive competencies allow the teacher to be flexible and adjust to changes and the unexpected. These competencies are needed by mediators. Teacher C was able to approach concepts in a relaxed manner, and explicitly taught the language of the subject. She was able to adapt to the unexpected and still deliver a good lesson.

By her own accounts Teacher C had not reached the multidimensional level of bioliteracy (Uno & Bybee, 1994). She demonstrated a good understanding of the subject in the lessons that I observed, and it is possible that she underestimated her ability.

Many teachers have no experience of fieldwork and little knowledge of whole organism ecology (Bowen & Roth, 2007; Barker, Slingsby & Tilling, 2003). It is thus not surprising that ecology was not taught as Learning Outcome 3 required.

In South Africa, dysfunctional schools are schools that have a 40% or lower matriculation (Grade 12) pass rate (Bipath, 2002). Bloch (2009) states that 60 – 80% of schools in South Africa are dysfunctional. The school reported on here was not dysfunctional. It had a matriculation pass rate of around 80% in 2009. The teachers were in their classes at the beginning of the lesson, and when teachers were absent classes were supervised by other teachers who had a free period. The learners were disciplined and polite. There were textbooks and the school was organised. The teaching methods were no different to those used in the classes I observed in a (more advantaged) Model C school while conducting research for my Masters degree (Raitt, 2004). The difference lies in the lack of facilities in this school and in the home backgrounds of many of the learners, which does not support academic activities. A lack of facilities and poor home backgrounds do not constitute dysfunctionality. If that were the case then no one would ever overcome a disadvantaged background. There is also the fact that it is possible to teach core concepts in biology without the use of expensive apparatus, if one understands the subject.

6.6.1 Problems noted during classroom observations

6.6.1.1 Class size

The suggested maximum class size for Grades 8 & 9 is 37 learners per teacher (DoE, 2002b:7), a number considered by Finn, Pannozzo, & Achilles (2003:352) to be "truly overcrowded". The explanation of why classes as large as 45-55 learners then still exist lies in the following statement, which still holds true in 2011:

> However, educational needs are always greater than the budgetary provision for education. To effect redress and improve equity, therefore, public expenditures must be specially targeted to the needs of the poorest. (DoE, 1997b:6).

We gather from this that there is simply not enough money to employ more teachers.

Research has shown that learners who have been in smaller classes have higher levels of achievement than learners in larger classes. Disadvantaged learners and those from low-income homes benefit more than others from having been in a small class. It must be noted that the "large" classes referred to in these articles are classes with 22 - 26 learners (Nye, Hedges, & Konstantopoulos, 1999) or 31 learners (Nystrand & Graff, 2001). The advantage of having been in a small class is maintained through high school and into college (Achilles, Finn & Pate-Bain, 2002; Biddle & Berliner, 2002). Wasley (2002:6) related the difficulty she had keeping track of learners at risk in a class of 40 learners. She concluded that disadvantaged students end up in the "largest classes with the least experienced teachers and the least engaging curriculum and instructional strategies". This ties in with Finn *et al* (2003) suggestion that the positive effect on academic achievement that being a member of a small class brings about can be the result of the fact that in a small class every individual is more visible. They believe it may be a result of the interaction of being visible and feeling a greater sense of belonging that brings about increased academic engagement, and thus greater academic achievement (Finn *et al*, 2003).

Class periods are short and thus time management is essential and a skill that comes through practice and experience. All these factors apply to most South African schools. What is significant for Teacher A is that Holloway (2002) notes that teachers of small classes have more time to prepare their lessons. Teacher A's classes had between 45 and 52 learners per class, which meant that they were larger than most classes.

Since it is unlikely that South Africa will reduce class size in the near future, it would be useful to look at the characteristics of successful large schools.

- A safe, orderly and positive environment is created (Sailors, Hoffman, & Matthee, 2007).
- The curriculum is chosen to promote specific skills and abilities. "Soft options" or subjects that do not require sustained effort to master and also do not contribute much to skills development are discarded (Allen, 2002).
- Teachers collaborate in curriculum development across disciplines, and aim to solve problems. e.g. English teacher, history teacher, design teacher and media specialist worked together on an interdisciplinary project making large models buildings of various ancient cultures (Allen, 2002).
- Strong relationships are built between staff and learners, e.g. "Home bases", where the same group of learners meet with the same teacher every morning for their entire high school career. These groups consist of 15 students and meet for 20 minutes a day to share anything relevant - even home problems

(Allen, 2002). In this way students are monitored and those at risk are helped before problems escalate (Darling-Hammond, Ancess & Ort, 2002).

- All staff members take a personal interest in learners, from the principal down; e.g. at one school of 2 900 learners, the principal met with 30 students at a time, and within three weeks had met with the entire school body. He shared his vision for the school with them (Darling-Hammond *et al*, 2002).
- Teachers expect as much from the learners as they would from their own children, and because of strong relationships the learners know that teachers are there for them when they need help (Darling-Hammond *et al*, 2002).
- Academic skills are explicitly taught (Darling-Hammond *et al*, 2002).
- Instructional time is used optimally and not wasted on administrative tasks (Darling-Hammond *et al*, 2002).
- Positive home-school relationships are maintained. (Sailors *et al*, 2007; Allen, 2002; Darling-Hammond *et al*, 2002).

6.6.1.2 Structure of National Curriculum Statements (NCS)

Teacher A noted that the textbook was of no help to him in ecology since it did not have a section dealing with ecology at all. A topic is dealt with in the WCED Grade 8 Work Schedules but is not covered in the Grade 8 textbook. This discrepancy might be the result of the way in which the NCS is structured (See Appendix F). In the NCS the phases are given and the content is not divided according to Grade. This means that all content for Grade 7 to 9 (Senior Phase) is listed in one continuous list and not assigned to a particular grade. It is thus difficult for authors of textbooks to decide which content should be covered in which grade. Teachers at School A follow the work schedule supplied by the Western Cape Education Department, and find it difficult to make good use of the textbook.

There is supposed to be integration across Learning Areas (e.g. Mathematics, Social Sciences, Life Science) in Outcomes-Based Education, but integration within a single learning area does not occur. In Teacher C's class learners kept their notes on content examined in Paper 1 in one book, and that examined in Paper 2 in another book. Learners then would automatically compartmentalise the content in the same way in their minds. Teaching content in "Strands" further compartmentalises it, e.g. respiration in Senior Phase, Grades 7-9 (GET) is only mentioned in the section on Matter and Materials, almost as though it did not belong under Life and Living, and yet, together with photosynthesis, it is basic to life on earth.

Both photosynthesis and respiration are covered in Grade 10 and not revisited at all. This means that their content is given in a much abbreviated form, with no biochemical details given because they are considered too difficult for a Grade 10 learner, and chemistry has been removed from the Life Science Curriculum entirely.

> Atoms will not be dealt with in this course because not all learners taking Life Sciences will have knowledge of Physical Science beyond the General Education and Training (GET) level. (DoE, 2007:2)

> **Molecules for life:** Organic molecules made up of C,H,O & some also contain other elements, e.g. N and P….*[Use simple diagrams representing molecules. Review briefly why these substances are needed in plants and animals i.e. build on GET prior knowledge. No detail of structure or function here- functions will be dealt with in later sections where appropriate. This is a brief introduction to the molecules making up organisms][This links to nutrition]* (DoE, 2007:10).

In Grade 12 the learners cover human reproduction and HIV/AIDS among other topics. It is naïve to believe that no learners are sexually active before Grade 12. This information is needed far earlier and could be covered in Grade 10 without losing any depth.

From the above discussion it is clear that the large classes make the teaching of ecology difficult, and that the teachers themselves admit to finding it difficult to teach ecology. Furthermore, the lack of teaching and learning materials which explicitly guide the teaching of ecology is a challenge facing teachers in certain grades. The compartmentalisation of content into specific strands and the removal of chemistry from the Life Sciences curriculum have serious consequences. This is elaborated on when looking at the knowledge of university students in the next chapter.

In Chapter 7 the results of the questionnaires and interviews with university students doing various Life Science courses and final year pre-service Life and Natural Science teachers will be discussed and related to the findings from the high school questionnaire.

CHAPTER 7: UNIVERSITY RESULTS AND DISCUSSION

7.1 Introduction

In this chapter the results obtained from the administration of the misconceptions questionnaire to first-year Life Science students are discussed and related to the high school results. As a reminder, first-year university students participated in this study in order for the researcher to gauge what the ecology knowledge base of Grade 12 students would possibly look like. We were not allowed access to Grade 12 learners at any high schools, as per WCED regulations. As noted in Chapter 4 all Life Science students (LSC) registered in the first week of the first semester, and we accessed this group before any formal teaching started. LSC 151 and LSC 152 were part of the Extended Curriculum Programme. The Extended Curriculum Programme (ECP) allows students whose grades would not normally allow them entry to university an opportunity to do a degree. Their first year is completed over two years. LSC 151 and 152 are extended-year courses, and are equivalent to the semester courses LSC 141 and 142 respectively.

Nine volunteers studying for the Post-Graduate Certificate in Education completed the misconceptions questionnaire. These students, pre-service teachers, have already completed degrees in the subjects they expect to teach. The purpose of including the pre-service teachers was to augment the results of the school visits in terms of trying to understand how teachers, or in this case prospective teachers, navigate the terrain of ecology.

I interviewed seven students from LSC 152 and seven from the LSC 151 class. Only one student from the LSC 141 class agreed to be interviewed. There were fifteen interviews in total.

It is impossible to separate the results from the discussion in this chapter. The interviews were done to verify the misconceptions and thus form part of the results and part of the discussion.

7.2 Questionnaire and interview results and discussion for life sciences and pre-service teachers

Misconceptions will be discussed under the following headings: Photosynthesis and respiration, Food chains and food webs and finally, Population dynamics.

7.2.1 Photosynthesis and respiration

Below is a summary of the misconceptions concerning photosynthesis and respiration held by students in the first and second-year Life Sciences courses, and the final-year pre-service teachers (PGCE).

Table 7.1 Misconceptions held about photosynthesis and respiration

MISCONCEPTION HELD	Percentage who have that misconception					
	141 1st year n=158	151 1st year N=70	152 1st year n=58	142 1st year n=107	BDC 212 2nd year n=21	PGCE Pre-service n=9
Photosynthesis is the plant's form of respiration	15.2	40	49.1	18.7	9.5	11.1
Plants do not respire	24.1	8.6	10.5	36.4	9.5	33.3
Do not understand why respiration is necessary	12.7	32.9	42.1	44.9	42.9	22.2
Respiration is equated with breathing	3.8	18.6	17.5	0.9	0	33.3
Humans don't need plants in order to survive	7.6	17.1	24.6	5.6	4.8	11.1
Plants get most of their carbon from the soil through their roots	18.4	25.7	24.6	22.4	23.8	11.1
Plant cells do not have mitochondria	2.5	0	8.8	0	0	0
Respiration is associated with sweating	3.2	2.9	0	0	0	0

It is clear from Table 7.1 that there was some confusion about what photosynthesis and respiration actually are, and so it appears that these two concepts were not fully understood generally by the different groups. The students doing the LSC 152 course had covered photosynthesis and respiration in LSC 151 the previous year. It was thus very interesting to note that nearly half of them (49.1%) still held the misconception that photosynthesis is the plant's form of respiration, and a further 10.5% believed that plants do not respire at all. The interviews confirmed that this was accurate, as shown by the excerpts from an interview (Interview 080106-001 group interview) given below.

> RR Now in the questionnaire that I gave you in the beginning of the year, do you remember? The first question was "Respiration only takes place in animals; plants have photosynthesis instead of respiration." You had to agree or disagree with that statement, now P**** agreed with it. I think you all agreed with it. Now do you still agree with it, that "Respiration only takes place in animals; plants have photosynthesis instead of respiration"?
>
> SP,(SZk),(S24) Yes (nod from SZk).

Interview 080107-001 revealed a similar belief.

> S26 I think animals they inhale oxygen and they give off carbon dioxide and plants they give off oxygen that we breathe.
>
> RR So do … so plants don't have respiration?
>
> S26 They don't have respiration. They don't inhale oxygen. They don't give off carbon dioxide. They make carbon dioxide.

These students did not have the opportunity to work with others on problems in class. The class period was a simple lecture and very few questions were asked, as portrayed by one of the students:

> RR Was anybody in the class able to ask questions?
>
> S25 No because the way Mr ****** taught was, I don't know, he… how can I say? People didn't like… people didn't really like going to his class because if like, people would start talking or … then he would just walk out and then the lecture is finished. (Interview 080108-001)

This shows how persistent misconceptions are. Despite being taught the correct conceptions of photosynthesis and respiration, and writing at least two exams that covered the topic, students still held onto the misconceptions they had brought from school. These findings are consistent with those of Uno (2009), Köse (2008) and Eisen & Stavy (1988), who found that even students who were majoring in Biology still held this misconception. Köse (2008) suggests that it comes from the misconception held by teachers and from analogies such as "forests are the lungs of the planet". Many of the students gave as a reason for this answer the 'fact' that plants do not have lungs and therefore cannot respire. Kao (2007) found this to be a common misconception in Grades 7, 8 and 9. As noted in Chapter 5 the Grade 6 teacher said, "Plants breathe in carbon dioxide and they breathe out oxygen."

Unfortunately, nearly one quarter of the LSC 152 students believed that humans do not need plants, and if they died we could eat other things. They held this belief despite having covered photosynthesis in LSC 151 in the first year of the Extended Curriculum Programme. In each class there were a few individuals who believed that humans do not need plants. Even in the BDC 212 class (this is a second-year module) there was one person who did not believe that humans need plants, and one of the PGCE students (pre-service teachers) still believed that we do not need plants.

An interesting misconception that came out in the questionnaire but which I did not find in the literature was the linking of respiration and sweating (perspiration). At first I thought that this might just be a language problem, as many of the students do not have English as a home language; however, this was not confirmed in the interviews. An interview with an English-speaking student from the LSC 151 class revealed that it was not a language issue.

RR	With your test there was this association between animals sweating and respiration. Your comment with the first question "Respiration takes place in animals; plants have photosynthesis instead of respiration." Your response was "In animals they sweat when respiration happens if it is too hot or they need to cool down. In plants they don't sweat but use the sun to photosynthesize." I'd like to know the relationship between sweating and respiration.
S7	This is like from last year so like [that's fine] so its like a quarter gone in this instance so basically I'll just need time to get the answers. It's like respiration… Okay sweating is like something happens after you run… activity…
RR	Ah, so it's activity. I thought it was. Carry on.
S7	Oh okay. And then you obviously need moisture to cool you off. Respiration I think is … I'm not too sure I've still got it.
RR	So it was as I thought that you related respiration to sweating because of the extra activity and the sweating. [Mmm. (Nods head.)] Does respiration only take place when you indulge.. engage in a lot of exercise and a lot of ….
S7	It happens in small amounts. So…um.. okay what is it you are asking me?

(Interview number 080109-002).

Many of the reasons given for agreeing or disagreeing with a statement cannot accurately be called misconceptions, since they just reveal the confusion that learners in high school experience in Life Science. It is possible that, given the same test on another day, they would have given a different but still invalid reason for agreeing or disagreeing with a statement. This was suggested by their responses to the interview questions. The following excerpt from an interview (Interview 080102-002 with a 151 student) illustrates the complete lack of understanding of biological concepts. I have used "…" to indicate a pause in speaking, when those being interviewed have left a sentence hanging.

RR The first question was "Respiration only takes place in animals; plants have photosynthesis instead of respiration." You had to agree or disagree. You said, "Plants don't reproduce or don't need the sun to reproduce." Can you explain?
S1 (151) Is this like my answer that I gave?
RR Yes. I've tabulated them all.
S1 How can I say? Plants don't need the sun to reproduce but you get the plants that reproduce at night for example… I can't give examples and what was the other question?
RR The question was, "Respiration only takes place in animals; plants have photosynthesis instead of respiration." Now you had to agree or disagree. Do you agree with this statement?
S1 Ja. [or do you ….] I agree on … I agree on that statement.
RR So then to you plants don't respire and animals do. So then photosynthesis takes the place of respiration.
S1 Ja.
RR Now what's the purpose of respiration?
S1 to produce more animals.
RR Respiration, not reproduction.
S1 Oh sorry.
RR Do you know what respiration is? Didn't you do it in matric?
S1 I can't remember what sections we did.

It would appear that the confusion that Carlisle & Flemming (2003) speak of, when students do not read the full word properly but focus on the suffix and hence confuse words like reproduction and respiration, is even found at university level.

Because of time constraints it was not possible to interview each student to confirm misconceptions, and thus, in view of the confusion shown in the excerpt above, I would suggest that the following were not actually misconceptions but simply revealed a lack of any understanding of photosynthesis and respiration: "Respiration takes place in plants when oxygen is absent"; and "Animals can photosynthesize". I think that if challenged on those statements the students would react in much the way the student above did. The other misconceptions listed in the table above have been reported in the literature (Köse, 2008; Kao, 2007; Amir & Tamir, 1994; Eisen & Stavy 1988).

This group of first-year students was the very first to come through the first Outcomes-based FET curriculum, and this could be the reason for their confusion about photosynthesis and respiration. I refer to this here because I feel that the university results reflect the consequences of the first FET syllabus (DoE, 2003). This syllabus gave very little direction, and Assessment Standards were difficult to interpret. In Learning Outcome 2, under "Structure, control and processes in basic life systems of plants and animals" for Grade 10, photosynthesis and respiration are given as follows:

Grade 10

- Energy release;
- Food production;
- Human nutrition and related diseases and allergies;
- Gaseous exchange and related diseases and allergies. (DoE, 2003:36).

This gives no indication of depth or detail of coverage. A qualified teacher would know what was included but a teacher who was under-qualified, like Teacher A, would have difficulty. Fortunately the syllabus used from 2008 onwards as contained in the National Curriculum Statement (DoE, 2007), and the new curriculum used from 2012 (DBE, 2010) are more explicit and should be easier for teachers to use, as shown below:

Table 7.2 A comparison of the 2007 & 2010 syllabus on photosynthesis

TOPIC	2007	2010
Photosynthesis	Definition of and description of process in words and symbols; intake of raw materials; trapping and storing of energy; formation of food in chloroplasts and its storage. *[No biochemical detail of light and dark phases required.]* The effects of variable amounts of light, carbon dioxide and temperature on the rate of photosynthesis	Process of photosynthesis using words and symbols; intake of raw materials; trapping and storing of energy; formation of food in chloroplasts and its storage. Release of oxygen. *(No biochemical detail of light and dark phases required.)* Importance of photosynthesis; release of oxygen; uptake of carbon dioxide from atmosphere; food production (trapping energy). The effects of variable amounts of light, carbon dioxide and temperature on the rate of photosynthesis The role of carbon dioxide enrichment; optimum light and optimum temperatures in greenhouse systems to improve crop yields. *(Link to Grade 10 and 11 environmental issues.)* **Role of ATP** as an important energy carrier in the cell

Table 7.3 A comparison of the 2007 & 2011 syllabus on respiration

TOPIC	2007	2011
Respiration	**Cellular respiration:** Definition of and description of process; uses of energy for living cells **Aerobic respiration:** definition of and description of process taking place in cytoplasm and mitochondria. Use words and symbols *[No biochemical detail of glycolysis, Krebs' cycle or oxidative phosphorylation is required.]* **Anaerobic respiration:** - definition of and description of process in words and symbols *[No biochemical detail of process is required.]* Production of lactic acid in muscles during exercise **Comparison** between aerobic respiration and anaerobic respiration in terms of raw materials required; products and relative amounts of energy released. **Role of ATP** as an important energy-carrier in the cell.	**Cellular respiration:** The process of respiration and uses of energy for living cells. **Aerobic respiration:** in cytoplasm and mitochondria. Use words and symbols Glycolysis, Krebs cycle or oxidative phosphorylation. *(No biochemical detail is required)* **Anaerobic respiration:** production of lactic acid in muscles during exercise, words and symbols *(No biochemical detail of process is required.)* □ role of anaerobic respiration in industry - brewing and bread-making **Comparison** between aerobic respiration and anaerobic respiration in terms of raw materials required; products and relative amounts of energy released.

(DoE, 2007 & DBE, 2010).

Both photosynthesis and respiration have been named explicitly and the detail in which they are to be studied is given clearly in both syllabi (DoE 2007 & DBE, 2011), whereas the previous curriculum (DoE, 2003) did not name the processes and gave absolutely no detail. It merely said "energy release" for respiration and "food production" for photosynthesis (DoE, 2003). The 2011 syllabus is still problematic because no biochemical details of the process of respiration are required.

Another reason for the lack of understanding of photosynthesis and respiration could be the quality of the teaching. As seen with Teacher A, there is an emphasis on rote teaching, with a lot of notes and no understanding of the concepts. When learners who have been taught this syllabus enrol for first-year Life Science, which is a service course for Dentistry, Microbiology, Biochemistry and Medical Bioscience at university, they suddenly find that they should have a deeper understanding of photosynthesis and respiration than they were exposed to at school (P McLaren Life Science 141 lecturer, personal communication 06:07:10). They do not remember anything about either topic, as the following quotation from an interview demonstrates:

> RR Okay, do you remember what the products of respiration were? What does respiration produce?
>
> S3 I clearly do not know. I tried to think now did we do it or did we not do it? Now I am thinking we did in Grade 10 and I don't think my brain allows me to think that far. Not right now. (Interview 080103-001)

7.2.2 Food chains and food webs

Table 7.4 Misconceptions held about food chains and food webs

MISCONCEPTION HELD	Percentage who have that misconception					
	141 n=158	151 n=70	152 n=58	142 n=107	BDC 212 n=21	PGCE n=9
Plants do not need nitrogen.	8.9	18.6	36.8	26.2	9.5	0
Any organism that provides food for another organism is a producer.	30.4	57.1	56.1	43.0	9.5	66.6
Those not directly in the same food chain are not affected by changes in another food chain.	5.7	10.0	14.0	5.6	0	11.1
Decomposers release some energy that is cycled back to plants.	38.6	38.6	24.6	n/a	n/a	n/a
Nutrients give energy.	34.2	27.1	29.8	n/a	n/a	n/a
Soil gives food to plants.	22.8	38.6	43.9	n/a	n/a	n/a
Any organism that provides food for another organism is a producer but since it consumes another it occupies two trophic levels.	15.2	1.4	14.0	0	0	11.1
Energy accumulates up the food chain because all energy is passed on.	10.1	20.0	10.5	10.3	0	33.3
A population consists of all organisms living in a particular area.	23.4	32.9	43.9	15.9	23.8	66.6

The high-school questionnaire showed that learners in high school have very little understanding of what a producer is or of the flow of energy, and thus to them a food chain is simply a record of who eats who. First-year university students have the same misconceptions that were highlighted by the high school questionnaire. Once again these may be attributable to the brevity of the syllabus (DoE, 2003).

Under "Environmental Studies" LO2 Grade 10 is given as follows:

> Grade 10
> - Biospheres, biomes and ecosystems.
> - Living and non-living resources, nutrient cycles and energy flow within an environment (DoE, 2003:38).

Table 7.4 gives no indication of the students' understanding of why plants need nitrogen. Because nitrogen is essential for the formation of proteins which include enzymes, it was difficult to declare a reason invalid although it was clear that the students did not know why nitrogen is important to plants. Many statements were vague and meaningless but could not be classified as misconceptions, e.g. "Nitrogen is needed for the growth of plants and vegetation." or "Plants need nitrogen that they receive from decomposers to strengthen themselves." Many of the students did not know what nitrogen is needed for but worked out that plants do need nitrogen by the fact that some of the fertilisers contain N:P:K. When questioned about why nitrogen is needed by plants, most students could not answer.

RR	Then question 2, "Plants do not need nitrogen". You said they need oxygen and CO_2.
S1	Doesn't only humans need nitrogen?
RR	What do humans use nitrogen for?
S1	I learnt it now just in the past weeks that we need carbohydrates C, H, N, P and so forth. (Interview 080102-002)

The following excerpt comes from an interview with an LSC 141 student who had already covered enzymes in class.

RR	Then the question number 2. You gave a valid answer but I don't have it written down but it was a very general one so I just want to check a little more. "Plants do not need nitrogen". Now you disagreed. [Ja] What do they need nitrogen for?
S1(141)	Nitrogen – you've got the process of the nitrogen fixation whereby … 'cause that will do fixation with the bacteria that is used to break down… I think it is used to break down enzymes or something in the roots but it is found in the roots of leguminous plants. So I ... the nitrogen… the question was they don't use nitrogen.
RR	The question was, "Plants do not need nitrogen". And you disagreed, quite correctly, but you gave a very general answer. I'm just asking what plants actually use the nitrogen for.
S1(141)	How do they use nitrogen? They use it when they break down the bacterias… the enzymes.
RR	Why do they need to break down the enzymes?
S1(141)	Okay an enzyme… I think an enzyme is … It consists of certain … what can I say?

The pre-service teachers were aware that plants needed nitrogen but their answers were very vague, so that it was clear that they did not know why it was needed. For example:

> Nitrogen is one of the main 3 gasses in the atmosphere, plants need it during gases exchange. (Student 4, PGCE).

Only two of the BDC 212 (second-year Life Science) students did not know that plants need nitrogen, which shows that by the second year of study students have begun to get a better understanding of biology.

The misconception listed by Chiromo (2001), that cows are producers because they produce milk and meat for us, was even found among the LSC 152, students some of whom believed that cows are producers because humans eat cows, thus any organism that provides food for another is a producer. This was also evident in Question 16 which stated that "*Producers do not occur in water.*" Many students responded that fish are producers.

Despite knowing a bit more about photosynthesis than about respiration, over one third of the LSC 151 and 152 classes believed that plants get most of their food from the soil. LSC 141 students were not much better, with 22.8% holding that misconception. This commonly-held misconception (Köse, 2008; Sundberg & Moncada, 1994) can possibly result from the way gardeners and sales people at the nurseries talk about "feeding" the plants with fertiliser and such things. It could also be the result of not having an accurate concept of what constitutes "food" (Lee & Diong, 1999).

7.2.3 Population dynamics

An understanding of population dynamics is particularly important if students are to get any sense of the ecological problems we face, since over-population is one of the major causes of ecological problems. Table 7.5 shows that there were few misconceptions about the term population.

Table 7.5 Misconceptions held about populations

MISCONCEPTION HELD	Percentage who have that misconception					
	141 n=158	151 n=70	152 n=58	142 n=107	BDC 212 n=21	PGCE n=9
All organisms in an area make up the population of that area.	26.6	2.6	43.9	37.4	23.8	66.6
Only humans have populations.	1.9	0	0	3	0	0
Includes living and non-living things.	3.8	4.2	1.8	0	0	0

Population dynamics was not adequately covered in high school. They were supposed to have covered population growth, limiting factors, and managing populations in high school. Many regarded "population" as a term describing the interaction of all organisms living in a specific area. One student claimed that her teacher had taught her this definition. I would have dismissed that claim if I had not observed a class (for the ACE course) where the teacher gave exactly the same definition.

RR What definition did your teacher give you of a population?
S3a A population is group of different organisms and animals living together.
RR Was that the definition your teacher gave you? What definition did your teacher give you of community?
S3a Community? It's like different groups of similar type things. (Interview 080103 002).

7.3 Discussion

These results show that students enter university with misconceptions which are brought from high school and that students did not gain an adequate understanding of ecology in high school. Despite the statement, "Integration is achieved within and across subjects and fields of learning" (DoE, 2003:3), the students did not gain an understanding in high school of how photosynthesis and respiration relate to ecology, and brought many misconceptions with them to university. Even after instruction some misconceptions persisted, as shown by the questionnaire results of the PGCE pre-service teachers.

Teaching at university is still largely in the lecture format (Lujan & DiCarlo, 2006; Allen & Tanner, 2005; Klionsky, 2004), and UWC is no exception to this. The lecture format and large classes tend to favour passive learning and encourage absorbing facts just long enough to pass the exam (Ebert-May, Brewer, & Allred, 1997). This way of learning does not challenge misconceptions. Misconceptions should be brought out into the open and confronted if there is to be conceptual change (Stamp, Armstrong & Biger, 2006; Hewson, Beeth, & Thorley, 1998). If conceptual change is to take place, lecturers need to make the range of students' ideas clear, and to encourage them to talk about their thought processes with another student or in a group so that they can think about their ideas (Hewson, *et al,* 1998). Students learn better when actively involved in constructing meaning. This may be achieved by using group work or pair-and-share assignments, even whole-class questions answered with clickers, and then require students to convince their neighbours of the correctness of an answer (Stamp *et al*, 2006; Knight & Wood, 2005; Klionsky, 2004; Ebert-May *et al,* 1997).

Even though it was a very small sample, the results from the pre-service teachers (PGCE students) raise several questions and concerns. Of the nine students who answered the questionnaire only four gave more than five valid answers. This led me to enquire about what the "relevant qualifications" were that had allowed them to enter the Postgraduate Certificate in Education course. The admission requirements for this course, according to the 2010 Faculty of Education Calendar (UWC, 2010), are that students have "an approved three-year (360) credit, level 6 university degree or national diploma structured for teaching purposes". This degree should be structured in one of the following ways:

Table 7.6 Requirements for entry to the PGCE course

Two approved subjects to second-year level OR
One approved subject to third-year and one to second-year level OR
Two approved subjects to second-year level and one approved subject to first- year level OR
One approved subject to third-year level and two other approved subjects to at least first year-level in the Sciences.

Table 7.7 Qualifications of students doing the PGCE course

Stud-ent	Degree	Life Science courses included in degree	Level at which they plan to teach	Valid answers (10 questions)
1	Diplomas in Reflexology & Massage Therapy;	Unable to determine this because I did not have access to the course outlines.	Life Science up to matric;	2
2	BSc Biodiversity and Conservation Biology;	Life Science courses up to third-year university;	Life Science up to matric;	9
3	B Ed III Maths & Natural Science	No Life Science courses at university;	Natural Science to Grade 9.	5
4	BSc Biotechnology;	First-year Life Science courses;	Life Science up to matric;	2
5	**BA Hons** Sport & Recreational Science **Management;**	No Life Science courses because this was oriented toward Management and courses were done in the Economics & Management Sciences Faculty. It was a **BA** to start with and not a **B Sc.**	Life Science up to matric;	3
6	B Ed Maths & English;	No Life Science courses;	Natural Science to Grade 9;	4
7	BSc Medical Bioscience (Anatomy & Physiology);	First-year Life Science courses;	Life Science up to matric;	3
8	BSc Chemistry & Physics;	No Life Science courses;	Natural Science to Grade 9;	5
9		First-year Life Science courses.	Life Science up to matric;	7

If these students are to teach Life Science one would expect a degree that included subjects from the Life Sciences. The nine students had the following academic qualifications:

Students 1, 3, 5, 6 and 8 did not have any university level course in Life Science. For Student 1 the Diplomas in Reflexology and Massage Therapy are not offered in the Department of Natural Medicine at all, so I could not find out what link the subjects had to Life Science, and why this student was allowed to offer Life Science up to Grade 12 when she so clearly did not have a good understanding of the subject. Student 3 was only going to teach Natural Science, which is consistent with his/her qualifications. Student 5 had no Life Science courses in his/her degree, as it was a Management degree and therefore included subjects from the Economics and Management faculty. The only subjects in the Sport and Recreation Science that relate to Life Science are the Health Development and Primary Health Care courses and Exercise Physiology, which would not help one understand Life Science. Student 8 was only going to teach Natural Science, which is consistent with his/her qualifications.

While observing the students as they completed the questionnaire I noted that Student 1 spent her time in the test trying to see the answers of Student 2 who was sitting next to her. I did not interfere, as it is easy to detect copying, and the fact that she needed to copy indicated that she did not understand the concepts behind the statements.

Brady (2008:606) makes it clear that "a major step in producing scientifically literate K-12 students is to develop scientifically literate teachers from the large group of educators who lack a good K-12 background in science and math". Table 7.7 leads one to question whether universities are training scientifically literate teachers.

In this chapter I have shown the persistence of misconceptions. These misconceptions are carried into university and even when contradicted in lectures, may still be held into second year and beyond, as the PGCE students' results show. I do not believe it is possible to determine beyond doubt exactly where these misconceptions come from, because the quality of teaching varies from one school to another. It is important to know that they exist, that they are persistent, and that they interfere with learning. It is also important to address the misconceptions, and teachers should be equipped with various techniques (e.g. Pedagogical Content Knowledge approach) to address the misconceptions adequately. Many of the concepts in ecology are best taught through fieldwork and a laboratory or hands-on approach. Teachers should be equipped with adequate laboratories, or research ways in which they can teach using what they have around them (e.g. bottle biology).

In the next chapter the study will be summarised, the research questions will be addressed, and I will draw some conclusions. The limitations of this study will be noted.

CHAPTER 8: SUMMARY AND CONCLUSION

8.1 Introduction

This study was undertaken to investigate what actually happens in the classroom when ecology is taught. More importantly it was focused on answering the following research questions:

1. How do teachers and learners navigate the terrain of ecology, and what are the associated conceptual understandings?
2. Is the teaching of ecology addressing important issues relevant to South African problems as suggested in the curriculum?
3. What is the range of teaching strategies used by teachers to teach ecological concepts, and do these strategies develop ecological concepts adequately?

A summary of the answers to these questions will be given in this chapter, and the limitations and significance of this study will also be considered.

8.2 How do teachers and learners navigate the terrain of ecology, and what are the associated conceptual understandings?

Most of the teachers that I observed found themselves in unfamiliar terrain when they taught the ecology section of the syllabus. They navigated the terrain hesitantly with the textbook as a map, and it was an inaccurate map and of necessity incomplete.

The fact that I did classroom observations in only two schools, and then only seven teachers' classes were observed, could lead to the conclusion that the results gave an inaccurate picture. In contrast to this, the 285 Life Science students who completed the questionnaire came from a wide range of schools throughout South Africa, including both Model C and township schools. These students were also very confused about ecological concepts and had many of the misconceptions found among the high school learners. It must also be remembered that these students represent those who were selected to study at UWC, and thus represented learners whose examination results were better than average. This showed that the findings from the two schools were not inaccurate.

8.2.1 What is the conceptual understanding of teachers?

Because of the nature of qualitative research the researcher has to remain sensitive to the feelings and dignity of the participants. This question was not directly investigated. It is nevertheless possible to deduce the conceptual understanding of the teachers from their lessons and from comments that were made about ecology.

In the primary school the Grade 4 teacher was very dependent on the prescribed textbook. She approved of the workbooks that had been bought for use. As noted in Chapter 4 these workbooks had many misconceptions. Since I did not observe a Natural Science lesson in this classroom I cannot judge Teacher G's level of bioliteracy. The Grade 5 teacher, Teacher D, was prepared to take learners out of the classroom and let them see what producers are, but she was not confident about teaching ecology. She had not yet reached the structural level of bioliteracy in Uno & Bybee's (1994) classification.

The Grades 6 and 7 teachers were confident in their teaching of natural science. The Grade 6 teacher was not as familiar with ecology and taught it in very general terms. She too had not quite reached the structural level of bioliteracy (Uno & Bybee, 1994). The Grade 7 teacher showed a better grasp of the subject and read very widely. She could have reached the multidimensional level of bioliteracy (Uno & Bybee, 1994). Teachers therefore had very different approaches to teaching ecology, and this was directly influenced by their level of comfort with the teaching of the subject matter and their knowledge of ecology.

Life Science is a very broad Learning Area, including anatomy and physiology, botany, ecology, genetics, geology, and zoology. While it is true that these are not covered at great depth, it is still necessary to understand the subjects in order to avoid misconceptions. It is unlikely that an ordinary teacher would have an in-depth knowledge of all the subjects mentioned.

Teachers tend to prefer to teach about animals rather than plants (Wandersee & Schussler, 1999). Wandersee and Schussler (1999) refer to this as "plant blindness". Teacher C admitted to me that she found it very difficult to teach ecology because it was difficult to capture the learners' interest. She did not have the background to teach ecology. Many teachers have no experience of fieldwork and little knowledge of whole-organism ecology (Bowen & Roth, 2007; Barker, Slingsby & Tilling, 2003). Teacher B volunteered no information about his qualifications but appeared competent and at ease teaching the subject. It appears that teachers navigate away from ecology, rush it, fear it, or avoid it.

Teacher A displayed no understanding of the definitions he wrote on the blackboard. He had only reached the functional level of bioliteracy (Uno & Bybee, 1994) and thus was not able to implement the intention of the curriculum. Teacher B's explanations in class revealed a level of bioliteracy of at least structural level and probably multidimensional level. Teacher C had reached the structural level of bioliteracy because she clearly understood the major conceptual schemes of biology. She was beginning to see the connections between areas in biology and therefore could be said to be approaching the multidimensional level of bioliteracy.

8.2.2 What is the conceptual understanding of learners?

The conceptual understanding of the primary school learners was not measured in any way, so I can make no estimate of what level of bioliteracy they had reached. As indicated, the data collected focused on observations of lessons only at the primary school level.

Ecology is a very broad subject, and learners find it difficult to grasp the basic principles. According to Çepne,Taş & Kőse (2006), an understanding of photosynthesis and respiration is necessary if learners are to understand food chains and energy flow through ecosystems. On the basis of the results from the misconceptions questionnaire, I found that most learners did not understand either photosynthesis or respiration, nor did they understand the flow of energy through an ecosystem. The questionnaire revealed that many learners were confused about trophic levels and were not sure on what basis an organism could be classified as a producer. Most of the misconceptions that were listed in the literature were found in this study.

It is clear from the findings that the majority of the high school learners were still approaching the nominal level of bioliteracy, where they could recognise a few of the terms used in biology but certainly could not understand them.

The university students, who came from many different schools and still had many misconceptions, showed that the difficulty in developing a conceptual understanding of ecology that I found in the high school A was not limited to that high school but is a more general feature in South African schools. The level of bioliteracy of the first-year students was at about functional level (Uno & Bybee, 1994). It must be remembered that this test was administered before they were exposed to any lectures. The second-year students had reached the structural level of bioliteracy. The pre-service teachers' levels of bioliteracy are cause for concern. Only four of the nine had definitely reached the structural level of bioliteracy and possibly the multidimensional level (Uno & Bybee, 1994). Two of the nine were still on the nominal level of bioliteracy, and they were going to teach Life Science up to Grade 12. Teachers who are not bioliterate themselves will not be able to lead learners to bioliteracy.

8.2.3 Are teachers comfortable teaching ecology?

Only Teacher B appeared to be comfortable teaching ecology. Three teachers, teachers A, C and D, expressly commented on how uncomfortable they felt about teaching ecology. This bears out Wagiet's (1991) findings that 71% of the teachers surveyed had received training at university, but still felt that they were not equipped to teach ecology.

There are resources that teachers could use to get ideas on how to approach their teaching, where these are freely available and problems can be discussed. For example, go to http://www.conceptcartoons.com/ where there are examples of concept cartoons. However, in the case of other resources, teachers would need to purchase them. This would be prohibitive, given the low resources budget of schools. There is also the problem that teachers have so much marking to do, and limited time to look for available resources.

8.3 Is the teaching of ecology addressing important issues relevant to South African problems as suggested in the curriculum?

8.3.1 Primary School

No issues relevant to the topics being studied were raised in the lessons I observed, but this question cannot be answered from the few lessons I observed.

8.3.2 High School

All the lessons observed in Teacher A's classroom dealt with biodiversity. The issues implicit in the topic were simply included in the notes given to the class. They were not discussed. The learners were just required to learn the list of issues affecting biodiversity. The focus of the lessons was on the "facts" to be learned.

In Grades 10 and 11 the issues implicit in ecology were not addressed in any of the lessons observed. In order to discuss issues the learners needed to have read at least a bit about the issues in order to be aware that they exist. Many of the learners in South Africa do not have access to libraries (Pretorius & Mampuru, 2007; de Vries & van den Merwe, 2004) and come from language-poor environments (Maarman, 2009), thus teachers wishing to fulfil the requirements of the NCS would have to provide readings on the issues concerned and then discuss them. In view of the learners' inability to read with understanding it is doubtful that they would be able to understand newspaper articles on ecological topics.

Simply bringing in flowers to dissect in Grade 11 inspired one of the learners to tell me that he thought he might enjoy studying botany at university. Others said that looking at real things was more interesting than looking at pictures. I was asked if I had broken the law by picking flowers, and when I said that I had picked them in my garden the learners were surprised. I had forgotten that many of them live in flats in a concrete jungle where there are no gardens. They need to see living examples of what they are studying.

The experiences of Breiting & Mogensen (1999) and Jensen (2004) with the Muvin DK programme in Denmark showed that the approach required by LO3 is possible and does increase the interest of learners in their environment, but it will be a long time before South African teachers are be able to implement anything like that. We lack the resources and the training of our teachers is inadequate.

8.4 What is the range of teaching strategies used by teachers to teach ecological concepts, and do these strategies develop ecological concepts adequately?

8.4.1 Primary School

The three primary school teachers who kindly allowed me into their classrooms were all concerned with encouraging the learners to think for themselves. There were no rhetorical questions. When a question was asked all teachers expected a carefully considered answer and waited for it. If an incorrect answer was given the teachers would ask a question that drew attention to the mistake, and they required learners to think about answers. Question–and-answer was used effectively by all three teachers.

Two of the teachers took their classes outside and had the learners look for producers and consumers. Both of them encouraged learners to look at things that they saw every day, and to put them into a food chain or to consider their impact on organisms in the environment.

The Grade 7 teacher, Teacher F, first allowed the learners to classify organisms according to characteristics they felt important. Learners had to explain their classification system to the class and questions were asked. Classification using scientific keys was then discussed, and learners reclassified the organisms pictured on the worksheet.

In every lesson observed learners were required to think and defend their ideas. There was no way of measuring whether or not the ecological concepts were adequately developed, because I could not administer the questionnaire.

8.4.2 High School

Every lesson observed in Teacher A's class followed the same pattern. He would give a brief explanation and ask a few questions but would not wait for answers, and in some cases actually ignored answers. He would then tell the learners to take out their notebooks and to copy down notes from the specified section of the blackboard. Much of his time was spent keeping the class quiet, though the classes were fairly well-behaved. The results from the misconceptions questionnaire revealed that this method did not adequately confront misconceptions in the ecological concepts of the learners, and thus did not help overcome the misconceptions.

Teacher B used "chalk and talk", but when he asked questions he expected answers and would ask questions to make learners think about their answers. He tried to develop reading ability by giving reading assignments from the textbook and requiring the groups of learners to discuss what they had read and come up with a summary. He was clearly aware of the difficulties learners have with reading. Teacher B could not allow the learners to do their own practical work because there was not enough space in his laboratory. The tables were pushed right up to the workbenches and it was difficult to get to the back of the classroom.

Despite his efforts to improve learners' reading ability and to make them think, the results of the misconceptions questionnaire demonstrate that these learners did not have well-developed ecological concepts. .

Teacher C used the question-and-answer method effectively. She also had learners hunt for information from textbooks and reference books. She took the learners out of the classroom and fielded questions about what they saw. When she could not answer a question she would tell the learners that she would look it up and that they were to search on the Internet too. She had smaller classes and was able to use her laboratory to do practical work.

I had no direct measure of whether these methods adequately developed ecological concepts in the learners, because I could not test the Grade 12 class and had to test the Grade 11 class before they had had any ecology lessons from Teacher C.

8.5 Limitations of this study

This study preceded the 2010 Curriculum and Assessment Policy Statement (CAPS) document (DBE, 2010). However the findings are still relevant because, while the CAPS curriculum does not include the environment in Specific Aim 3 (see Table 3.2), the content to be taught remains much the same.

The study was planned to include classroom observations from Grades 4 to 12 in Natural Science lessons and Life Science lessons dealing specifically with ecology, and the administration of a misconceptions questionnaire in each grade. This was not possible because no researcher is allowed into a Grade 12 classroom (Appendix A), and because the principal of the primary school selected would not allow me to administer the questionnaire nor was I allowed to observe as many classes as I asked to be allowed to observe, as explained in Section 4.5. Unfortunately, I was unable to overcome that problem. The problem of not being allowed into the Grade 12 classroom was partially overcome by the administration of the questionnaire to first-year Life Science students at university before they had attended any lectures, as explained in Section 4.5. A post-test only approach was therefore used with the university students.

Lessons were observed in two schools only. Thus the sample is too small to allow for statistical generalisations. Because of the 'thick description' given, naturalistic generalisations are possible (Freeman *et al*, 2007). Furthermore, thick description of the procedures, participating schools, and methods used in the study assists in overcoming possible bias and facilitates the replication of the study. The study does however point to some of the problems that exist in the teaching of ecology. The inclusion of the first-year Life Science students in the study gives support to the picture presented by the schools.

8.6 Further research

Another problem, and one that lies at the root of many learning difficulties, is the problem of language. This problem was discussed in Chapter 5. What needs to be noted here is that the idea that grammar is merely a means of deciding who belongs to the favoured class, as propounded by Sledd (1969), fails to take into account the need to make oneself clearly understood. Sledd (1969:1037) maintains that:

> In a school system run like ours by white businessmen, instruction in the mother tongue includes formal initiation into the linguistic prejudices of the middle class.

The examples listed in Chapter 6 would prove difficult for any group or class to interpret. An important part of science is being able to communicate the findings of science to others. Surely, speaking simple grammatically correct language would give learners access to knowledge that they need, and enable them to participate in the knowledge economy?

The issue of how language can be infused into the teaching of Life Science and other subjects needs to be researched. Mother-tongue instruction is the ideal, but not one that can easily be reached in a country with eleven official languages.

The study of the teaching and learning of ecology at university level needs to be investigated further. It is clear that teachers are not being adequately prepared to teach ecology. Teachers receive their training at universities, and therefore science departments which prepare teachers in terms of content knowledge need to examine their curricula to ensure they are taught the correct conceptions. Furthermore, methods teaching should focus on "killer" courses like ecology, so that prospective teachers are equipped with teaching approaches that can ensure that ecology is taught properly at school level. Lecturers at university level have expressed concern about the preparedness of students for ecology, and further research at this level is therefore important. This study has shown that the Revised National Curriculum Statement provides a good framework for teaching ecology, but the curriculum has not been properly implemented.

8.7 The significance of this study

This study provides an indication of where problems are experienced in the teaching of ecology. It points to the fact that teachers are not adequately trained to teach this subject. At the moment there are few studies on how it is taught in South African schools.

Some of the lecturers in the Biodiversity and Conservation Biology Department are using misconceptions tests at the start of their courses, and have found the tests useful in guiding their teaching. These lecturers are attempting to participate in the scholarship of teaching and learning and hope to persuade other lecturers to follow suit.

The only reason why the lecturer for Life Science 141 is not using a misconceptions test is that his class of over 400 is too large for him to be able to process the questionnaire, and he has no one to help with marking. A way around this problem would be to use concept cartoons to highlight misconceptions, and then have the class vote on views expressed in the concept cartoon. Universities have access to electronic marking techniques which can also be explored.

8.8 Conclusion

The high school studied was not a dysfunctional school, yet there were problems with the teaching of ecology. If, as Bloch (2009) says, 60% to 80% of the schools in South Africa are dysfunctional, then it follows that there are problems with the way ecology is taught in South African schools. Evidence from this study suggests that a conceptual understanding of ecology is not being developed in learners. The teachers themselves admit to finding it difficult to teach ecology, yet an understanding of this subject is essential if we are to avoid compounding the environmental problems we face. A quantitative study to determine the extent of the problems with teaching ecology in the country would be useful in planning strategies for its teaching.

Education reforms imposed from above are rarely successful (Hargreaves, 2003). Changing the curriculum yet again is unlikely to improve the situation. Since it is teachers who actually determine what is taught in the classroom and how it is taught, it would be logical to focus on the quality of the training given to teachers if we wish to improve the quality of teaching (Hudson & Ginns, 2007). In order for teachers to be successful they need to be ready and willing to teach. They must have a deep understanding of the concepts and principles of their subject area and of pedagogy. They must be able to learn from experience and reflection, and must be able to work as part of a learning community. They must think of teaching as more than "telling", and learning as more than "repeating or restating" (Shulman & Shulman, 2004).

This was clearly not the case with the PGCE students (pre-service teachers) in this study. The results of the misconceptions questionnaire revealed that only one had the content knowledge necessary to teach up to Grade 12. The selection of prospective teachers needs to be done with more care. It would also be necessary to check that the prospective teachers actually understand the curriculum content they are going to teach. Education lecturers and Science lecturers should therefore work together to produce teachers who have the content knowledge and the pedagogical knowledge necessary to produce scientifically literate learners.

As stated, Life Science is a broad field and biologists can specialise to the point where they are isolated from each other, e.g. molecular biologists from ecologists (Barker *et al,* 2003). Barker *et al* (2003) note that many teachers now come from a background of microbiology or physiology, and have no experience of field work. Bowen & Roth (2007) believe that teachers, curriculum developers and researchers often neglect ecology in schools. Training teachers in the Life Sciences needs more attention than it is given. There is a need for training in practical ecology, since teachers are expected to have Grade 10 learners studying an ecosystem of their choice.

Teachers need a teacher journal or magazine that will be specific to the South African situation. As Teacher B noted, materials need to be translated into as many of the languages used in this country as possible, since teachers do not have time to first look for resources and then to translate them into another language. If scientists could be persuaded to write in a style that would be understood by the general public they could contribute to a teachers' journal and provide interesting insights, which teachers could use to stimulate discussion in classes. The didactical transposition of what is written in science is very important, because this knowledge takes a very long time before it gets into textbooks.

I found that it was very difficult to get into schools to do research. What happens in the classroom remains a black box, so it is difficult to monitor the implementation of policy. Principals and teachers have been criticised so frequently, and are often blamed for problems which have a political origin and are not of their making. They feel that they do not need yet another researcher who will heap yet more criticism on them. I have attempted to show how difficult it is for teachers to teach ecology when Life Science is such a broad topic and teachers are not adequately trained. They are not responsible for the inadequacy of their training.

This study raised important insights with regard to a number of issues in terms of how teachers and learners navigate the terrain of ecology. There can be no doubt that knowledge of ecology and ecoliteracy is important for the survival of our planet. However, there are a number of challenges standing in the way of people achieving the levels of bioliteracy or ecoliteracy that can lead to the changes we need to see in our world. Teachers in the main are avoiding or fear teaching ecology, as can be seen in this study, or they do not have adequate conceptual understanding of ecology to do it justice. Teacher pre-service training for the teaching of important topics like ecology needs to be addressed at university level, and a pedagogical content-knowledge approach would probably best suit this development.

The latter would focus on the content knowledge and the teaching strategies best suited to the development of ecological thinking, and at the same time address serious misconceptions students have about the topic. Misconceptions are resistant to change, as this study has shown. Teaching strategies need to address this phenomenon by paying attention to the prior knowledge of students.

The approach to ecology advocated by Learning Outcome 3 in the Revised National Curriculum Statement (DoE, 2003) would, if applied as shown in Chapter 3, be sufficient to produce ecologically literate learners, but unfortunately this approach has been abandoned in the new CAPS curriculum.

Finally, only a bioliterate, ecoliterate population can hold politicians accountable for their lack of concern for the environment. Our constitution states expressly that:

> Everyone has the right –
> (a) to an environment that is not harmful to their health or well-being; and
> (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
> (i) prevent pollution and ecological degradation;
> (ii) promote conservation; and
> (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.
> (The Constitution of the Republic of South Africa, Act 108 of 1996)

We will never achieve this if we do not know what is harmful to the environment and do not have the will to act to protect our environment. It starts with education and a focus on ecoliteracy.

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Appendix A Letter of permission to do research in schools

Navrae
Enquiries **Dr RS Cornelissen**
IMibuzo

Telefoon
Telephone **(021) 467-2286**
IFoni

Faks
Fax **(021) 425-7445**
IFeksi

Verwysing
Reference **20090831-0039**
ISalathiso

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

Mrs R Raitt

Dear Mrs R Raitt

RESEARCH PROPOSAL: STUDY OF HOW ECOLOGY IS TAUGHT IN SCHOOLS

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

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **1 September 2009 to 30 September 2010**.
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:
    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.

Signed: Ronald S. Cornelissen
for: **HEAD: EDUCATION**

DATE: 31 August 2009

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GRAND CENTRAL TOWERS, LOWER PARLIAMENT STREET, PRIVATE BAG X9114, CAPE TOWN 8000

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Appendix B Results of pilot test

Summary Test Trialled (questions only)

1 Respiration only takes place in animals; plants have photosynthesis instead of respiration.

2 Carnivores have more power than herbivores.

3 A cow is a producer because it produces milk and meat which we eat to make us strong.

4 If plants and seaweeds disappeared from the earth and sea, I would eventually ?

5 Populations increase until carrying capacity is reached and then they crash or go extinct.

6 A human baby, born normally, can never be identical to either of its parents.

7 Plants have no means of defending themselves against herbivores.

8 The process of respiration provides plants with their energy.

9 Animals can build their own carbohydrates from the food they take in.

10 Plants get their carbon from the soil through their roots.

11 A population consists of all organisms living in a particular area.

12 It is possible to have more consumers than producers .

13 Decomposers release some energy that is cycled back to plants.

14 Soil is a biotic component of the ecosystem because it gives food to plants.

15 An organism may occupy more than one trophic level in a food web.

16 Producers do not occur in water.

17 Natural selection kills [NS does not kill per se, rather they die - out so I guess it is the expression that I am not 100%happy with] those individuals of a species which lack the characteristics that would have enabled them to survive and reproduce successfully in their environment.

18 Energy is lost at each trophic level of the food chain.

Table B1 Percentage valid answers in Trial Test

Q No.	1	2	3	4	5	6	7	8	9
%	22	61	22	83	0	39	78	44	50
Q. No.	10	11	12	13	14	15	16	17	18
%	44	67	0	1	39	78	72	72	61

SOME MISCONCEPTIONS

1a Photosynthesis

Photosynthesis takes place in plants because plants need the sun to "respirate" because they have chlorophyll.

Photosynthesis and respiration can be found only in plants. It can't be found in animals.

Plants undergo photosynthesis and animals undergo respiration.

1b Respiration

Animals contain mitochondria, plants don't.

Animals respirate to get oxygen.

2a Carnivores

Carnivores have more energy because they are in the highest trophic level.

Carnivores eat protein, which is a big source of energy in comparison with plants.

Carnivores get more nutrients than herbivores and they eat fatty acids which are stored as energy.

2b Herbivores

Herbivores have less energy because they don't get proteins.

Energy sources are missing for herbivores.

3 Fourteen of them agree that cows are producers because they produce milk and meat that we eat to grow strong.

4 They do not know what carrying capacity is.

5 They believe that populations crash when carrying capacity is reached.

6 Most of them believe that energy accumulates up the food chain so that tertiary consumers have lots of energy.

7 They all agree that plants can protect themselves, using poison or thorns, etc.

8 They do not understand why respiration is necessary.

9 The learners do not realise that animals break down plant carbohydrates so that they can use the monomers to build their own types of carbohydrates.

10 Some of them believe that plants get carbon dioxide from the soil. Some believe that plants get protein through their roots. One suggested that plants get carbon from water.

11 Since they had not done population dynamics, most do not know what a

population is.

12 Learners do not realise that it is possible to have more consumers than producers.

13 They believe that decomposers release energy for the plants.

14 Half the class believes that soil is a biotic factor because it provides nutrients for the plants.

15 Most of them realise that the same organisms can occupy different trophic levels in a food web.

16 Four learners stated that fish are producers.

17 All of them agree that "Natural Selection kills…"

18 Most understand that energy is lost at each trophic level.

Recommendations

1 Question 2: delete "energy or".

2 Question 6: delete whole question as it is basically the same as Question 2.

3 Question 12: delete "secondary"

4 Question 13 needs reworking, so that they(?) focus on Decomposers and energy release and not on plants.

5 Check phrasing of Question 14. They ( ) may not see the gap between "a" and "biotic".

6 Question 18 is not clear. I don't know how to phrase it to show that energy is lost. Maybe delete it?

7 Consider removing Question 5, as population dynamics is done late in Grade 12 (I think).

Appendix C: Classroom Observation Schedule

CLASSROOM OBSERVATION SCHEDULE

SCHOOL:__________________ DATE:____________________________ TIME:______________

EDUCATOR: _______________ TOPIC: __________________________ No. LEARNERS: ______

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	3
Whole class																																					
Small group																																					
Individual																																					
Other																																					
Listening to educator																																					
Observing demonstrations																																					
Copying																																					
Reading																																					
Writing/giving answers																																					
Preparing/clearing away																																					
Doing practical work																																					
Creative writing/drawing																																					
Listening to learner feedback																																					
Discussing																																					
Other																																					
Educator instructions																																					
Explanations from educator																																					
Educator led questioning																																					
Educator passive																																					
Learner led questions																																					
Learner led input																																					
Other																																					

Notes

Appendix D: Teacher's consent form

DEPARTMENT OF BIODIVERSITY AND CONSERVATION BIOLOGY

Private Bag X17, Belville, 7535
South Africa
Tel: +27 (0) 21 959 2301
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Website: www.uwc.ac.za

Because of the importance of ecology in lifestyle and sustainability of resources, the teaching of ecology in schools is being investigated under the leadership of Dr Lorna Holtman of the University of the Western Cape.

TEACHER'S CONSENT FORM

I …………………………………………….. hereby agree voluntarily to participate in the research on the understanding that I will not be identified. I understand that I may withdraw from this research at any time should I feel the need to do so. The purpose of the research has been explained to me.

Signature: ………………………………………… Date: …………………………

Appendix E: Tests

The Grades 8 and 9 test is given in full to demonstrate the format. The rest are given in summary form with just a list of questions.

Pre-test/Post-test Grades 8 & 9

Name: ________________________________

Pre-/post test survey: Conceptual Inventory about Ecology.

Directions:
Each question in this test has two parts. You must decide whether you agree with the statement or whether you disagree with it. Put a tick next to "Agree" or next to "Disagree", whichever you decide is correct.
In the second part you explain, in your own words, why you agreed or disagreed with the statement.

1 Plants use oxygen.

Agree ________ Disagree ___________

Please explain your choice:

2. A cow is a producer within a food chain because it produces milk and meat which we eat.

Agree ________ Disagree ___________

Please explain your choice:

3 A dragonfly is not an animal.

Agree ________ Disagree ___________

Please explain your choice:

4 If plants and seaweeds disappeared from the earth and sea, I would die.

Agree ________ Disagree ___________

Please explain your choice:

5 Plants get most of their food from the soil.

Agree ________ Disagree ___________

Please explain your choice:

6 There are **no** producers in water.

Agree ________ Disagree ___________

Please explain your choice:

7

Dinosaurs did exist.

Agree ________ Disagree ___________

Please explain your choice:

8 All that plants need is light, water and minerals from the soil.

Agree ________ Disagree ___________

Please explain your choice:

Summary of Grades 10 & 11 Test

1 Respiration only takes place in animals; plants have photosynthesis instead of respiration

2 Plants need a suitable source of nitrogen, otherwise they will die.

3 A cow is a producer within a food chain because it produces milk and meat which we eat.

4 If plants, seaweeds and phytoplankton disappeared from the earth and sea, I would die.

5 A dragonfly is not an animal.

6 Decomposers release some energy that is cycled back to plants.

7 Soil is one of the biotic components of the ecosystem because it gives mineral salts and water to plants.

8 An organism may occupy more than one trophic level in a food web.

9 Producers **do not** occur in water.

10 Energy is lost at each trophic level of the food chain.

Pre-test/Post-test 1 Life Science

Summary

1 Respiration only takes place in animals; plants have photosynthesis instead of respiration.

2 Plants need a suitable source of nitrogen, otherwise they will die.

3 A cow is a producer within a food chain because it produces milk and meat which we eat to make us strong.

4 If plants, seaweeds and phytoplankton disappeared from the earth and sea, I would eventually die.

5 Populations increase until carrying capacity is reached, and then they crash or go extinct.

6 A human baby, born normally, can never be identical to either of its parents.

7 Plants have no means of defending themselves against herbivores.

8 The process of respiration provides plants with their energy.

9 Animals can build their own carbohydrates from the food they take in.

10 Plants get most of their carbon from the soil through their roots.

11 A population consists of all organisms living in a particular area.

12 It is possible to have more consumers than producers in a pyramid of numbers.

13 Decomposers release some energy that is cycled back to plants.

14 Soil is one of the biotic components of the ecosystem because it gives food to plants.

15 An organism may occupy more than one trophic level in a food web.

16 Producers **do not** occur in water.

17 Natural selection kills those individuals of a species which lack the characteristics that would have enabled them to survive and reproduce successfully in their environment.

18 Energy is lost at each trophic level of the food chain.

Summary of Post-test: Life Science and Education

1 Respiration only takes place in animals; plants have photosynthesis instead of respiration.

2 Plants need a suitable source of nitrogen, otherwise they will die.

3 A cow is a producer within a food chain because it produces milk and meat which we eat to make us strong.

4 If plants, seaweeds and phytoplankton disappeared from the earth and sea, I would die.

5 A human baby, born normally, can never be identical to either of its parents.

6 Plants get most of their carbon from the soil through their roots.

7 The process of respiration provides plants with their energy.

8 Producers **do not** occur in water.

9 Energy is lost at each trophic level of the food chain.

10 A population consists of all organisms living in a particular area.

APPENDIX F Revised National Curriculum Statement for the Natural Sciences *Senior Phase* (Grades 7 to 9). (DoE, 2002).

Life Processes and Healthy Living	Interactions in Environment	Biodiversity, Change and Continuity
	Senior Phase	
◆ Humans go through physical changes as they age; puberty means that the body is ready for sexual reproduction. ◆ Human reproduction begins with the fusion of sex cells from mother and father, carrying the patterns for some characteristics of each. ◆ Conception is followed by a sequence of changes in the mother's body, and during this period the future health of the unborn child can be affected. ◆ Knowledge of how to prevent the transmission of sexually transmitted diseases, including the HIVirus, must be followed by behaviour choices. ◆ Green plants use energy from the sun, water and carbon dioxide from the air to make food by photosynthesis. This chemical reaction is central to the survival of all organisms living on earth. ◆ Animals, including humans, require protein, fat, carbohydrates, minerals, vitamins and water. Food taken in is absorbed into the body via the intestine. Surplus food is stored as fat or carbohydrate. ◆ Animals, including humans, have a circulatory system which includes the heart, veins, arteries and capillaries, and	◆ Human reproduction is more than conception and birth; it involves adults raising children, which requires judgement and values and usually depends on the behaviour of other people in a community and environment. ◆ Each species of animal has characteristic behaviours which enable it to feed, find a mate, breed, raise young, live in a population of the same species, or escape threats in its particular environment. These behaviours have arisen over long periods of time that the species population has been living in the same environment. ◆ All organisms have adaptations for survival in their habitats (such as adaptations for maintaining their water balance, obtaining and eating the kind of food they need, reproduction, protection or escape from predators.) ◆ An ecosystem maintains numerous food webs and competition for food among different individuals and populations. South Africa has certain ecosystems which have exceptional biodiversity. All uses of these areas must be based on principles of sustainable development	◆ Offspring of organisms differ in small ways from their parents and generally from each other. This is called variation in a species. ◆ Natural selection kills those individuals of a species which lack the characteristics that would have enabled them to survive and reproduce successfully in their environment. Individuals which have characteristics suited to the environment reproduce successfully and some of their offspring carry the successful characteristics. Natural selection is accelerated when the environment changes; this can lead to the extinction of species. ◆ Variations in human biological characteristics such as skin colour, height, and so on. have been used to categorise groups of people. These biological differences do not indicate differences in innate abilities of the groups concerned. Therefore, such categorisation of groups by biological differences is neither scientifically valid nor exact; it is a social construct. ◆ Biodiversity enables ecosystems to sustain life and recover from changes to the environment. Loss of
	Core Knowledge and Concepts in Life and Living	

(Above tables not complete)