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Teaching evolution in a new curriculum: Life Sciences teachers' concerns and needs.

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CHAPTER 1

An introduction to the study and its context

1.1 OVERVIEW OF THE STUDY

This study investigated the concerns and needs of South African *Life Sciences* teachers having to teach evolution for the first time to Grade 12 in 2008. The data were gathered through questionnaires completed by two groups of teachers (n = 45 and n = 74) from various districts in Gauteng, attending in-service training workshops. The workshops were designed to provide support for teachers who were preparing to teach evolution.

This chapter explains the context of the study, and the specific problem which motivated the study. Its focal point is the challenges *Life Sciences* teachers are faced with regarding the teaching of evolution for the first time.

1.2 THE INTRODUCTION OF THE NEW SCHOOL CURRICULUM IN SOUTH AFRICA

1.2.1 A brief history

A new curriculum, originally named *Curriculum 2005,* was introduced in South African schools during the period 1998 – 2008. Implementation started with Grade R-9, at the *General Education and Training* level (GET). It was finally fully implemented by 2008 at the *Further Education and Training* (FET) level, which involves the final three years of secondary schooling (Grade 10 – 12).

The new curriculum placed new demands on the teachers, who are required to make changes in their classroom practices as well as teaching new content. Many senior teachers who did not teach at the *General Education and Training* level encountered, for the first time, nine new classroom practices teachers are required to implement (Sanders and Kasalu, 2004) and the philosophy behind them. The senior teachers had not previously been trained in the requirements of the new curriculum but were expected to change their classroom practices in similar ways. The descriptions of the requirements, as explained by Sanders and Kasalu (2004), are outlined in Appendix A. Two of the nine requirements of the new South African curriculum, "learner-centeredness" and "activity-based learning", are important when dealing with the teaching of evolution. Learner-centeredness is important because teachers need to understand the diversity of religious groups and cater for such diversity in classrooms. Activity-based learning is important as there is a wide variety of exciting activities that can help learners to understand evolution. Although the two requirements are important, neither of these is the focus of my study.

A review of the curriculum conducted in 2000 identified a number of problems with the new curriculum (Chisholm *et al.*, 2000). One of these, for sciences, was the lack of prescribed content. The curriculum was then revised and implementation of the Revised National Curriculum Statement Grade R-9 in the Foundation Phase was planned for 2004 (Department of Education, 2002).

1.2.2 Inclusion of the new topic of evolution in the *Life Sciences* curriculum

In addition to requiring teachers to change their way of doing things, the new curriculum includes a number of topics which teachers have never taught before, some of which they themselves have never been taught (Stears, 2006). One such topic in the *Life Sciences* curriculum is that of "evolution". The topic of evolution was taught in Grade 12 for the first time in 2008, and made up 25% of the *Life Sciences* curriculum and the final matriculation examination for that subject.

Prior to 1994 the topic evolution had no place in the South African biology curriculum (Lever, 2002). The government of the time held a perception that evolution clashed with their religious beliefs (Dempster and Hugo, 2006). The Christian National Education policy introduced in 1948 had forbidden the inclusion of evolution in the biology curriculum as the education system was grounded in the light of God's revelation (Lever, 2002). This policy, which was used as a guiding principle for all South African education for almost fifty years, made it clear that *"the spirit and direction in every subject taught must correspond to the Christian and National life- and world-view … and that in no subject may anti-Christian or unChristian … propaganda be conveyed"* (Lever, 2002, 34).

Even after the government changed in 1994, evolutionary theory did not immediately find a place in school biological curriculum (Science in Africa, 2003), although the Department of Education accepted that there was a need to wipe out the *"worst of apartheid-inspired material"* (Lever, 2002, 41), and to modernize school curricula. Evolutionary theory continued to be viewed with negativity and fear by some in positions of power, as characterized by a quote from the then Minister of Education, Professor Sibusiso Bhengu, who stated that *"it's not a priority"* (Science in Africa, 2003, 1).

Evolution was only introduced after the revision of *Curriculum 2005*. In the Revised National Curriculum Statement for *Natural Sciences,* some statements were incorporated in the intermediate phase (Grade 4-6) and senior phase (Grade 7-9) which spelled out basic concepts about evolution to be taught (see Table 1 on the next page). The table is included so that the reader can see the extent of evolution-related topics that are dealt with in the Revised National Curriculum Statement for *Natural Sciences.* However, the *Natural Sciences* Revised National Curriculum Statement does not use the term "evolution", and the basic concepts provided in the GET curriculum in *Natural Sciences* are dealt with under different knowledge strands in isolation, not as a unit (see Table 1). In *Social Sciences* Grade 7, the term "evolution" is used, in a section about "human evolution". Three aspect are covered on human evolution "*early hominid discoveries in South Africa and East Africa", "becoming human in southern Africa"* and *"rock art as an expression of hunter-gatherer society and world view"* (Department of Education, 2002, 149). In spite of this content there was little publicity or controversy about the teaching of evolution. *Natural Sciences* teachers seemed not be worried about evolution-related concepts incorporated in the curriculum, possibly because the term evolution was not used or because the concept of evolution was not externally examinable. Many South African teachers omit difficult content when it is not externally examined.

Table 1: Evolution-related content extracts from the *Natural Sciences* Revised National Curriculum Statement Grade R-9 (Department of Education, 2002)

Core knowledge and concepts in the *Life and living* strand		
	Interactions in environments	**Biodiversity, change and continuity**
Intermediate phase		• *Sexual reproduction is the process by which two individual plants or animals produce another generation of individuals. The next generation's individuals look like the parents but always have slight differences ('variation') from their parents and from each other.* • *South Africa has a rich fossil record of animals and plants which lived million of years ago. Many of those animals and plants were different from ones we see nowadays. Some plants and animals nowadays have strong similarities to fossils of ancient plants and animals. We infer from the fossil record and other geological observations that the diversity of living things, natural environments and climates were different in those long-ago times.(Links with fossils in Planet Earth and Beyond)*
Senior phase	•*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.)*	• *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[1] 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* [better] *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 extinction of species.* • *Human activities, such as the introduction of alien species, habitat destruction, population growth, pollution and over-consumption, result in the loss of biodiversity. This becomes evident when more species become endangered, or, ultimately, extinct.* • *Extinctions also occur through natural events. Mass extinctions have occurred in the past, suggesting huge changes to environments have occurred. However, these changes occurred very slowly, compared to the fast rate at which humans can destroy plant and animal species. (Links with Planet Earth and Beyond)*
Core knowledge and concepts in the *Planet Earth and beyond* strand		
Unifying statements	**Atmosphere and weather**	**The changing Earth**
	The atmosphere is a system which interacts with the land, lakes and oceans and which transfers energy and water from place to place.	*The Earth is composed of materials which are continually being changed by forces on and under the surface.*
Intermediate phase		• *Erosion of the land creates the landforms that we see and also results in the deposition of rock particles that may be lithified to form sedimentary rocks. Erosion and deposition can be very slow and gradual or it can occur in short catastrophic events like floods.* • *Fossils are the remains of life forms that have been preserved in stone. Fossils are evidence that life, climates and environments in the past were very different from those of today.(Links with Life and Living)*
Senior phase	• *Human activities and natural events can slightly change the composition and temperature of the atmosphere. Some effects of these small changes may be changes in annual weather patterns and long-term changes in rainfall and climate.*	• *Many of the organisms in South Africa's fossil record cannot be easily classified into groups of organisms alive today, and some are found in places where present-day conditions would not be suitable for them. This is evidence that life and conditions on the surface of the earth have changed through time.(Links with Life and Living)* • *Fossil fuels such as coal, gas and oil are remains of plants and animals that were buried and fossilized at high pressures. These fuels are not renewable in our lifetimes. (Links with Energy and Change)*

[1] This wording could lead to misconceptions.

The implementation of the National Curriculum Statement at FET level started in Grade 10 in 2006 and continued up to Grade 11 in 2007 and Grade 12 in 2008. However, in the *Life Sciences* National Curriculum Statement dated 2003 there is no mention of evolution-related topics below Grade 12 level. All evolution topics were covered only in Grade 12. The topics included *"origin of species, evolution theories, mutation, natural selection, macro-evolution and speciation, fundamental aspects of fossil studies, Cradle of mankind – South Africa? biological evidence of evolution of populations,* and *popular theories of mass extinction"* (Department of Education, 2003, 40). In November 2005 some learning programme guidelines came out that included several evolution-related concepts in Grade 10 and 11 (Department of Education, 2005), contrary to the National Curriculum Statement of that time. However, teachers were unaware of this as many do not look at the guidelines in detail. Furthermore, the textbook writers had already produced textbooks for 2006 and 2007, based on the National Curriculum Statement, and did not include evolution in Grade 10 or Grade 11 textbooks. Because teachers tend to teach only what is in the textbooks, evolution was not being taught below Grade 12, which was in line with the National Curriculum Statement. The *Life Sciences* learning programme guideline dated November 2005 indicates that in Grade 10 and 11 there is little development of the concept that life evolves by natural selection and that fossils are evidence of ancient life, as summarized in Table 2 on the next page. *Speciation, common descent, mutation* and *evolution by natural selection* remain topics to be covered in Grade 12, thus providing a full coverage of the theory of evolution. Genetics, which is a vital prerequisite topic underpinning evolution, is divorced from the teaching of evolution in that it is included in the content area '*Tissues, cells and molecular studies'* for Grade 12. Table 2 summarizes the evolution-related content for the FET level.

Once the topic of evolution was introduced at FET level great concerns about the possible controversy became apparent, possibly because the term "evolution" was used and because the topic of evolution was externally examinable so had to be taught. A number of concerns were voiced by teachers who attended a workshop on teacher training about the teaching of evolution (Mail and Guardian, 2007). Teachers made comments such as *"I am disappointed about the fact that evolution attacks God's creation…", "I am totally against evolution"*. The latter comment was based on an opinion that the teaching of evolution is only suitable for atheist teachers and should, therefore, be voluntary (Mail and Guardian, 2007, 3). Some black teachers said evolution was a "racist theory" after a video *Tiny Human: finding Hobbits in Flores* was shown at the workshop. The video traces the origin of tiny prehistoric humans (short and dark-skinned) in Indonesia (Mail and Guardian, 2007). The teachers were cited in the Mail and Guardian (2007, 3) as saying evolution *"terribly undermines black people, everything bad gets a black colour. It means that we are apes".*

There seem to be problems associated with the structure of content as laid out in the Learning programme guideline Grade 10 – 12. Firstly, the content is laid out under different learning outcomes, and is divided into "content areas", which is likely to fragment the teaching of evolution. This fragmentation is confusing in terms of the logical structure. Secondly, the content is structured in a manner that there is repetition across grade levels with no guidelines to teachers of how to handle this. Thirdly, the sequence is problematic as some concepts covered before evolution need evolution theory to be understood properly (e.g. malaria resistance).

Table 2: A summary of evolution-related concepts covered in different content areas in the *Life Sciences* (Department of Education, 2005)

Grade	**Learning outcome 1:** The learner is able to confidently explore and investigate phenomena relevant to *Life Sciences* by using scientific inquiry and problem solving 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 interrelationships of science, technology, indigenous knowledge, the environment and society.
Content area: Tissues, cells, and molecular studies			
10	• *collect latest research information on diseases e. g. malaria resistance* • *investigate human influences on the environment e.g. introduction of exotic species*		
11	The NCS just repeats the Grade 10 wording above		
12	The NCS just repeats the Grade 10 wording above	• *explain the importance of meiosis as a mechanism to introduce genetic variation (random segregation of chromosomes and crossing over)* • *explain inheritance with reference to meiosis*	
Content area: Diversity, change and continuity			
10	• *collect and analyze data on evolutionary trends in a population e.g. human beings*	• *significance and value of biodiversity to ecosystem function and human survival* e.g. *adaptations for survival*	• *adaptation and survival* • *extinction of species* • *fossil records, museum, zoos* • *population changes over time* • *beliefs about creation and evolution* • *changes of knowledge through contested nature and diverse perception of evolution*
11	The NCS just repeats the Grade 10 wording above	The NCS just [repeats the Grade 10 wording above]	The NCS just repeats the Grade 10 wording above
12	The NCS just repeats the Grade 10 wording above	• *biological evidence of evolution of populations and fundamental aspects of fossil studies* - *fossilization* - *fossils as evidence in ancient life* - *interpretation of the fossil record by means of homologous and analogous structures* • *origin of species – evolutionary theories, mutation, variation, natural selection, macro evolution and speciation* • *popular theories of mass extinction* - *continental drift* - *ice age* - *volcano activity* - *heating and cooling of the atmosphere* - *disease* • *Cradle of Mankind – South Africa?* - *where are humans thought to have originated?* - *differentiate between anthropology, palaeontology, and archaeology, possible origin of humankind on Earth*	The NCS just repeats the Grade 10 wording above

Certain authors, when considering content to be covered in a curriculum, divide the content into substantive and syntactic structures of knowledge, based on the categorization of Schwab (1978). This idea is used by Shulman (1986), who describes the substantive structure of knowledge as structures that refer to *"the variety of ways in which the basic concepts and principles of the discipline are organized to incorporate its facts"* (Shulman, 1986, 9). Abd-El-Khalik (2006, 4) refers to the substantive structure of a discipline as ideas that are *"inter-related and connected"*. The syntactic structure of content, on the other hand, has to do with *"different methods of verification and justification of conclusions"* (Schwab, 1978, 246). Syntactic knowledge deals with the ways in which truth is established in the discipline, which involves a set of rules used to determine *"what is legitimate"* or *"which claim has greater warrant"* if there are conflicting views within the science community (Shulman, 1986, 9). In the case of evolution this would include evidence which supports evolution (e.g. comparative anatomy, paleontology, biochemistry, embryology, biogeography). However, the division of the content into substantive and syntactic structures is not central to my study and will not be discussed further. South African teachers were confused enough by the division of the content in the learning programme guidelines and did not need something extra (i.e. the division of content into substantive and syntactic structures) which is rather abstract and difficult to have to consider.

Even before the new FET *Life Sciences* curriculum was fully implemented a revised *Life Sciences* curriculum was issued to schools as "A new content framework for the subject *Life Sciences* as listed in the National Curriculum Statement Grades 10-12 (General)" (Gauteng Department of Education, 2007). The curriculum statement was totally revised again and was published in June 2011 as the Curriculum and Assessment Policy Statement (CAPS) *Life Sciences* Grades 10, 11 and 12 (Department of Basic Education, 2011), to be implemented from 2012. However, these revisions happened subsequent to my study and are not directly relevant to my study. The details are therefore included only in an appendix (Appendix B).

1.3 WHY EVOLUTION IS IMPORTANT IN BIOLOGY

Numerous authors deal with the importance of including evolution in biology (Clough, 1994; Haury, 1996; Rutledge and Warden, 2000; Rutledge and Mitchell, 2002; Wuerth, 2004; Berger, 2006 and Cavallo and McCall, 2008), although often just as part of an introductory discussion to their literature review. Many of them are simply summarizing earlier papers. There are four main reasons why evolution is important in biology. Evolution is seen as the theory that ties together all life sciences and other science disciplines (Farber, 2003; Cavallo and McCall, 2008), provides scientific explanations to answer intriguing questions about life on Earth (Rutledge and Warden, 2000; National Academy of Sciences and Institute of Medicine, 2008), underpins technological advances (National Academy of Sciences and Institute of Medicine, 2008), and has great practical and problem-solving value to scientists (Scharmann, 2005). These are explained in more detail in the following sections.

1.3.1 Evolution as a unifying theme

Evolution is considered a unifying concept in *Life Sciences* and other scientific disciplines (Clough, 1994; Haury, 1996; Rutledge and Warden, 2000; Rutledge and Mitchell, 2002; Cavallo and McCall, 2008; Wuerth, 2004; and Berger, 2006) because of the common idea of change over time. A unifying

theme means a unifying idea that gives us a framework for understanding a vast body of unconnected facts. A unifying idea serves as a thread that weaves together a whole lot of diverse facts (Lever, 2002) into a meaningful system (Farber, 2003). Without this thread *Life Sciences* and other scientific disciplines would be disjointed, and much within these sciences would not make any sense.

In biology the idea that populations of organisms may change slowly over time links various topics such as genetics, palaeontology, comparative anatomy and embryology, and biogeography (Farber, 2003; Cavallo and McCall, 2008). For example, every time palaeontologists put a spade in the Earth and bring out fossils, natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms (Haury, 1996). Evolutionary theory ties all unconnected facts together into a coherent whole, affirming a claim made by Dobzansky (1973, 129) that biology without the light of evolution *"becomes a pile of sundry facts - some of them interesting or curious but making no meaningful picture as whole".*

Evolution (the idea that things change with time) is also a unifying theme in scientific disciplines other than biology, such as astronomy, geology, physics and anthropology (National Science Teachers Association, 1997). If we look, for example, at the planet's physical environment, stars, and life on the planet Earth, we see things that are different from the past. Evolutionary theory provides a framing device for us to understand the changes through time.

1.3.2 Evolution has broad explanatory powers

The National Association of Biology Teachers (2008) says evolution provides a scientific explanation for the wide biodiversity on Earth (past and present) and how this biodiversity is based on common ancestry. As an explanatory tool evolution becomes a key to the process of knowing that enables us to understand the fundamental principles and processes involved in all life forms (Dempster and Hugo, 2006). Rutledge and Warden (2000) point out that the theory of evolution also affords an opportunity for exploring the "why" and "how" questions asked about the wide variety of life forms. For example, evolution gives us answers about why some organisms that share anatomical and functional characteristics are not related, while other organisms that are different are related. Evolution explains that homologous structures of different organisms (e.g. bones of the fore-limb of humans, birds, dolphins and bats) are similar because these organisms evolved from a common ancestor that also had that structure (National Association of Biology Teachers, 2008). Evolutionary theory explains that homologous structures are the result of divergent evolution, which occurs when some members of a species take a different evolutionary pathway than others of that species (Holley, 2009). Differences in environmental conditions and selective pressures over time may result in formation of a new species branching off from the original species group (Holley, 2009).

Furthermore, evolution provides us with an understanding of why some unrelated organisms may acquire analogous structures which may make them look similar. Analogies evolve separately in response to common environmental conditions. For example, many unrelated organisms have developed wings for flight (butterflies, birds, bats) to adapt to the environment (Raven, Johnson, Losos and Singer, 2005). Similar structures in unrelated or only distantly related organisms are an example of convergent evolution.

1.3.3 Evolution underpins technological advances

The literature shows that usefulness of evolution goes beyond its power as an explanatory tool, and that an understanding of evolution has led to important practical applications in various fields, like agriculture, health sciences, biotechnology, and conservation and management of the environment (National Academy of Sciences and Institute of Medicine, 2008).

Bull and Wichman (2001) argue that there were technological advances even before the role of evolutionary theory was widely understood, for example, artificial selection was used to improve agricultural crops and animals. But Pigliucci (2005) adds that artificial selection is still being used by biotechnology research companies when designing products. Modern researchers try to improve on nature in ways that benefit humans. Artificial selection has been combined with modern technological means, e.g. incorporating a gene that possesses advantageous traits, to modify crops genetically. Genetic modification of crops has been used to increase crop resistance to pests and pathogens, as well as to harsh weather conditions (National Academy of Sciences and Institute of Medicine, 2008). These applications have improved the quality of life for humans.

1.3.4 Evolution is a powerful problem-solving tool

Bull and Wichman (2001) point out that Darwin's theory of "descent with modification" becomes a powerful problem-solving tool for health researchers to trace the origins of newly evolved pathogens and to suggest ways to fight these pathogens using evolutionary principles. Understanding evolutionary theory has helped health researchers to develop strategies to deal with life-threatening human diseases like severe acute respiratory syndrome (SARS) (National Academy of Sciences and Institute of Medicine, 2008), HIV's resistance to new drugs (Wuerth, 2004), swine flu, and tuberculosis-resistant strains. Recently health researchers have been faced with the challenge of coming up with a strategy to combat the SARS that erupted worldwide. They first identified the pathogen and then traced its origins based on their understanding of evolutionary theory. They then found other related pathogens and they used the information gathered to develop treatments for the disease and vaccines to prevent infections from the virus (National Academy of Sciences and Institute of Medicine, 2008).

HIV's resistance to new drugs is an increasingly serious problem that the health discipline is faced with (Wuerth, 2004; and Scharmann, 2005). Pigliucci (2005) points out that health researchers are utilizing evolutionary theory as a basis to identify the virus's resistance to drugs. Understanding how viruses evolve allowed researchers to develop multiple antibiotics in a careful regimen. Multiple antibiotics provide a complex environment and *"living organisms simply cannot evolve resistance to complex environments because they cannot count on multiple divisions happening at the same time"* (Pigliucci, 2005).

1.4 WHY EDUCATORS WANT EVOLUTION INCLUDED IN BIOLOGY CURRICULA

Wuerth (2004) points out that the inclusion of evolution in biology curricula helps students to understand scientific processes and explanations, as well as helping them understand how populations

change, which helps to explain biodiversity. In a study conducted by Miller, Scott and Okamotto (2006) adults surveyed in European countries and Japan were less likely to reject evolution than American adults, one reason being a better scientific understanding, e.g. of modern genetics.

Dempster and Hugo (2006:106) claim that the introduction of evolution into the school curriculum in South Africa will provide learners with meaningful access to higher order concepts (i.e. concepts that seek the ultimate causes of structures and functioning of organisms, *"those relating to the historical and evolutionary factors that account for the observed structures and functioning"*, and alternative ways of thinking).

Dempster and Hugo (2006) assert that South African professional biologists and academics have welcomed the inclusion of evolution in the school biology curriculum. The biologists and academics believe that there are abundant natural resources in South Africa that would encourage learners to construct their own knowledge when taught about evolutionary theory. The natural resources include a "*wealth of biodiversity and environments, a well documented fossil record, an extensive geological record, active research programmes investigating evolutionary relationships and mechanisms of evolution among extant species and a network of museums and national parks"* (Dempster and Hugo, 2006: 107).

1.5 PROBLEMS WITH TEACHING EVOLUTION

In many papers, evolutionary theory has been identified as a very controversial topic that is difficult to teach (for example, Rutledge and Warden, 2000; and Wuerth 2004). Despite the fact that the theory of evolution has gained acceptance by the scientific community as a fundamental underpinning concept of *Life Sciences* (Trani, 2004; and Hildebrand, Bilica and Capps, 2006) it has been met with pessimism by the general public (Rutledge and Mitchell, 2002; Farber, 2004; Miller *et al.*, 2006; Rutledge and Sadler, 2007; and Wiles and Branch, 2008), including some teachers with little scientific background (Aguillard, 1999). The research suggests that there are four main reasons why evolution is such a difficult topic to teach: evolution is a controversial topic (Wuerth, 2004); teachers have poor content knowledge, full of misconceptions (Rutledge and Mitchell, 2002; Chuang, 2003); teachers are not adequately prepared to teach evolution (Moore and Kraemer, 2005; Wiles and Branch, 2008); and teachers are concerned about having to teach evolution and many do not, therefore, teach it adequately (Stears, 2006). These factors are described in more detail in the next few sections.

1.5.1 Evolution is a controversial topic to teach

The teaching of evolution affects different stakeholders in the education process in different ways:

- ***Evolution conflicts with many teachers' own beliefs:*** Some of the teachers surveyed in various studies reported that evolution conflicts with their own personal beliefs (for example, Rutledge and Mitchell, 2002; and Moore, 2008), and as such they did not want to accept the theory of evolution (Aguillard, 1999; and Trani, 2004). There are many consequences associated with the conflict, the most common of which is that the teachers avoid teaching evolutionary theory in their biology classrooms (Hildebrand *et al.*, 2006). In one study, conducted by Rutledge and

Mitchell (2002), a survey of 552 biology teachers in Indiana schools showed that 43% of the teachers avoided evolution in their teaching or only mentioned it briefly. Moore (2008) reported that 14% of the 107 teachers in one study did not teach evolution at all.

Secondly, some teachers present evolutionary theory superficially (Aguillard, 1999). Teachers who teach evolution superficially may be those who get to it late during the year (Scharmann, 1993; Hildebrand *et al.,* 2006) and rush through the work just before the final exams. Alternatively, the teachers may just not place great emphasis on it, as was the case with 28% of the teachers in a study by Moore (2008). If evolutionary theory is taught superficially learners may be denied an opportunity to engage in discussions about the descent of man and origin of life, as reported by Schilders, Sloep, Peled and Boersma (2009), thus leaving learners without adequate conceptual understanding.

Thirdly, Hildebrand *et al.* (2006) assert that some teachers tell their learners to learn about evolution but that they do not have to believe evolutionary theory, as was the case with Wilson, a distinguished biologist in the United States, who glued a disclaimer into every biology textbook handed to learners saying that *"you don't have to believe in the evolution taught here if you don't want to"* (Hemenway, 1999, 7). Some tell their learners that they should just learn it for exam purposes (Sanders, 2010).

Fourthly, some American teachers unlawfully incorporate creationism (Moore, 2008) and intelligent design as an alternative science to evolutionary theory, thus sabotaging the teaching of evolution (Hildebrand *et al.,* 2006). Teaching creationism in biology classes was declared unlawful in the United States of America (Tatina, 1989), where the Supreme Court established, with *Epperson v. Arkansas,* 1968, that it is against the First Amendment of the American Constitution to teach the views of a particular religious group. Thus anyone teach creationism (which is a particular religious belief) would be breaking the law (Moore, Jensen and Hatch, 2003). Moore and Kraemer (2005, 462) found that one in five Minnesota biology teachers never-the-less teach creationism because they *"feel that their beliefs in creationism justify breaking the law".* This was also true with 24% of the 107 Minnesota teachers in a study by Moore (2008), who included both evolution and creationism in their biology lessons.

- ***Evolution conflicts with many learners' beliefs:*** Even if biology teachers accept the legitimacy of the theory of evolution, and are willing to teach it, they may be faced with a dilemma as some learners hold conflicting worldviews and reject evolution (Matthews, 2001), or experience inner tension, or just switch off in class and become passive participants (Scharmann, 1993; Schilders *et al*., 2009). In a study by Schilders *et al*. (2009, 117-118) Dutch learners made claims like evolution *"cannot be true, because God created it all",* or*"evolution is also a belief, you just believe in it or you do not", "it is just a theory, because you have no proof whatsoever".* The claims imply that the learners seem to have a limited understanding of the nature of science and evolutionary theory (Schilders *et al*., 2009).

- ***Parents, community members, and school administrators exert pressures which influence how well evolution can be taught:*** Moore and Kraemer (2005) point out that many American teachers

are experiencing pressure from their communities, including parents, to teach creation science and intelligent design. For example, in a study by Moore (2004, 861) a teacher made a comment expressing frustration that *"parents pressure me, and it's just not worth it to teach evolution"*. The pressure has contributed to de-emphasis of evolution in classrooms (Rutledge and Mitchell, 2002). While some teachers respond to the pressure by avoiding evolution (Moore and Kraemer, 2005), other teachers respond to the pressure by teaching *"creation science"* and *"intelligent design"* as alternatives to evolutionary theory (Zimmerman, 1987; Trani, 2004; and Bandoli, 2008).

1.5.2 Teachers' poor content knowledge

Wuerth (2004) claims that some biology teachers lack appropriate knowledge for understanding evolutionary theory. There are two main points emerging from the literature that I have read. Firstly, teachers seem to have poor conceptual understanding. Secondly, teachers also have misconceptions about evolution.

- ***Teachers' poor conceptual understanding:*** Rutledge and Warden (2000) and Stears (2006) claim that teachers who have a problem with acceptance of evolution often have a poor conceptual understanding, a factor admitted by teachers in a recent South African study (Sanders, 2010). Many factors contribute to poor conceptual understanding. Even teachers who do accept evolution may not understand it well. One factor may be that teachers themselves never studied evolution, as is the case in South Africa (Stears, 2006). In America, Moore (2002) states that some Louisiana high school teachers do not recall hearing the word "evolution" in their college biology courses. Aguillard (1999) found that 78% of the 18 American teachers he interviewed reported their inadequate academic training. Another factor may be that some teachers who study evolution at the university level have achieved little success in their evolution course and still have poor conceptual understanding.

  Rutledge and Mitchell (2002) report on a survey of 235 American biology teachers, some of whom accepted evolution and some of whom did not. They were provided with a concept mapping activity to communicate their conceptions and knowledge structures of evolution. The study showed that teachers of the non-acceptance group generated concept maps that averaged only 5.7 concepts about evolution and 4.8 linkages of evolution concepts per map, compared to the 14 concepts and 16 linkages per map generated by the acceptance group.

- ***Teachers' misconceptions about evolution:*** According to Sanders (1993, 919) misconceptions are*"incorrect mental constructs that are firmly held ... and thus resistant to change".* Wandersee, Mintzes and Novak (1994, 179) describe a misconception as an imperfect understanding of a concept that is strongly held "*and is at variance with current scientific knowledge".* Weld and McNew (1999) assert that significant percentages of biology teachers hold a variety of misconceptions about evolution resulting in misinterpretation of the concept of evolution. Subsequently, their teaching becomes a mixture of their own everyday views and scientific ideas mentioned from the textbooks which distorts the theory of evolution. Table 3 on the next page shows prevalent misconceptions associated with evolution, based largely on the

University of Berkeley website (The University of California Museum of Paleontology, Berkeley, 2006). The misconceptions have been grouped into four main categories.

Table 3: Common misconception related to evolution

Misconception	Why this is a misconception
Misconceptions associated with conflicts between creation and evolution	
Evolution clashes with religion.	Science and religion are two ways of explaining the world. Religion is based on belief systems and science is based on empirical evidence, and the two can coexist without conflict.
The Earth is between 4000 and 6000 years old.	This is scientifically incorrect, as the young-earth creationists calculations were based on a literal interpretation of the description of creation in Genesis 1, which says the Earth was created in six days. However, the scientist's calculations are deduced from the ratios of different lead isotopes found on meteorites. These calculations result in estimated ages for the Earth of 4.42 to 4.56 billion years, with a best value of 4.54 billion years (Dalrymple, 1991).
Misconceptions to do with the nature of science	
Evolution is 'just' a theory so has little scientific credibility.	Scientific theories are explanations supported by a vast body of evidence. Confusion stems from what "theory" means in everyday language and in scientific contexts. Evolution is a well supported and broadly accepted theory, because it is not just a hunch (the everyday English meaning of 'theory'.
Evolution is a theory in crisis as it is continually debated by scientists.	Scientists agree that evolution is the best explanation for life's diversity because of the vast body of evidence supporting it. The focal point of their debates is *how* evolution occurred rather than *whether* evolution took place. That is, they may argue about the mechanisms of evolution. Those against evolution may hear about the debates about *how* evolution took place and misinterpret the arguments as debates about *whether* evolution occurs (The University of California Museum of Paleontology, Berkeley, 2006).
Gaps in the fossil record disprove evolution.	For a living organisms to be preserved it must have body parts that fossilize well (for example, bones), and live in a place with suitable environmental conditions for the formation of fossils. The conditions for fossilization are not common. This explains the gaps in the fossil record, which do not disprove evolution. Scientists always bear in mind that there will be gaps in the fossil record, and are also constantly discovering new intermediate fossils (see National Geographic, 2009).
Evolution is not science because it is neither observable nor testable.	Not all scientific investigations are dependent on experiments conducted in the laboratory or on direct observations. That is, evidence is not limited to seeing something happen before your eyes. For example, astronomers cannot hold stars in their hands but can learn about the universe by using evidence that has been gathered and make inferences from it.
Misconceptions associated with mechanisms of evolution	
Evolution "betters" organisms, increasing their complexity, like a climb up ladder of progress from lower animals to humans.	One important mechanism of evolution, *natural selection*, increases populations adaptations to the environment by allowing those organisms in a population with survival characteristics to survive and reproduce better so favourable genes increase in numbers in the gene pool of the population. Evolution applies in simple life forms (e.g. bacteria) which have hardly changed over time yet they remain successful (The University of California Museum of Paleontology, Berkeley, 2006).
Evolution occurs when organisms develop features they need to survive.	Natural selection cannot sense what a species or individual "needs". In a population there is genetic variation which is a basis for natural selection to act on. If individuals happen to have to have a genetic variation that allows them to survive a challenge better than others, or reproduce more than others, then those individuals will have more offspring in the next generation, and the population will evolve. If that genetic variation is not in a population, the population may survive anyway, reproduce less and may not evolve much (or may die out). But will not be granted what it "needs", by natural selection.
Natural selection involves organisms 'trying' to adapt.	Natural selection increases adaptation of a species to environment over time, but the process does not involve "trying". Natural selection involves selecting for individuals with survival genes in a population. Either an individual has survival genes to live longer and reproduce more than others, or it does not, and it cannot get the favourable genes by "trying".
Misconceptions to do with knowledge about evolution	
Evolution is a theory about the origin of life.	Darwin's theory of Evolution by natural selection explains how life has changed after its origin but does not say how life originated (Prinou, Halkia and Skordoulis, 2008). Other theories such as the big bang theory and creationist theories suggest how life started (Campbell, Reece, Urry, Cain, Wasserman, Minorsky and Jackson, 2008).
Life began when Earth was formed.	This misconception may arise from the religious creation story where the formation of Earth and the appearance of life appeared in the same week. Scientists think that the earliest form life appeared 3.4 billion years ago. The earliest evidence for life comes from fossilized cyanobacteria called stromatolites, estimated to be about 3.4 billion years old (Campbell *et al*., 2008).

The three most frequent misconceptions encountered in the literature are: evolution clashes with religion, evolution is 'just' a theory, and evolution 'betters' organisms. The first misconception is associated with the lack of understanding between evolution and religion. The misconception implies that one cannot believe in God and accept evolution. In fact some people, including many in the scientific community, are devotedly religious and also accept evolution (Ayala, 2000). This became evident as individuals in many denominations had signed a letter that endorses that the discoveries of modern science and religion may coexist (see discussion on Chapter 4, section 4.3.4, p. 61).

The second misconception, evolution is *"only a theory"* (Hemenway, 1999; Ayala, 2000; Antolin and Herbers, 2001), has to do with the lack of understanding of the nature of science, and the fact that a theory in science and a theory in everyday English have two different meanings. In ordinary language, a theory is considered to be an *"imperfect fact"* (Ayala, 2000), or to mean a *"guess"* (Chuang, 2003) or a tentative idea yet to be tested. The scientific definition of theory is rather different from the everyday meaning of the word. Theory in science refers *"to a comprehensive explanation of some aspect of nature that is supported by a vast body of evidence"* (National Academy of Sciences and Institute of Medicine, 2008, 11). This association points out that scientific ideas are only given "theory" status when the accumulated evidence leads scientists to believe that there seems to be no other viable explanation. A lack of understanding of the nature of science is an indication that people do not know enough about the theory of evolution to make informed opinions about it.

The third misconception is related with a misunderstanding of the mechanism of evolution, and the misconceptions do with knowledge about evolution have been explained in Table 3.

1.5.3 Teachers are inadequately trained to teach evolution

Stears (2006) claims that training offered by the Department of Education in South Africa, in science particularly, was not helping teachers to cope with challenges they face in the classroom and community. From informal talks with *Life Sciences* teachers, it appears that the teachers prior to 2006 never had specific training that paid attention to evolution and were never trained on how to approach the teaching of evolution in class. Training on the topic of evolution started to be offered by the educational institutions late in 2007 and early in 2008. At that time teachers were anxious about their inadequate knowledge. In an American study Antolin and Herbers (2001) point out that teachers who find themselves having to teach evolution for the first time are unlikely to understand the theory of evolution and its importance. Tatina (1989) says that in such situations teachers may favour the teaching of creationism. Tatina (1989, 278) warns that *"this is a dangerous situation because today's students will be making tomorrow's curriculum decisions on future boards of education".* Teachers should be provided with continuing training that pays attention to small details (Antolin and Herbers, 2001), and in-service training on evolution should aim at preparing biology teachers in the philosophy and methodology of science (Tatina, 1989).

1.5.4 Teachers' concerns about teaching evolution

The research literature shows that teachers worldwide seem to have other concerns about the teaching of evolution. Many teachers:

- feel inadequate if they have never taught evolution and have therefore never paid attention to the topic (Stears, 2006);
- are worried about lack of resources in their schools (Scharmann, 1993),
- are concerned about content coverage from textbooks, as some textbooks cover evolution too deeply and others cover it too shallowly (Tatina, 1989),
- are worried about learners' resistance (Scharmann, 1993).

1.6 THE SPECIFIC PROBLEM WHICH MOTIVATED THE STUDY

Based on my discussions with *Life Sciences* teachers in cluster meetings in one school district in Gauteng the year before the teaching of evolution began, it appeared that teachers were skeptical about their ability to explain the theory of evolution, mainly because they did not have the content knowledge to teach the subject. The teachers criticized a Department of Education workshop they had attended (provided to train FET teachers on policy matters and on evolution) as "inadequate". The criticisms included the following aspects:

- Facilitators themselves did not seem to understand the content they were teaching about, both in terms of policy and in terms of evolution theory.
- Facilitators used chalk-and-talk methods, and did not role-model the expected approaches.
- Too much information was given as hand-outs for self-study and a lot of important information was not covered in the workshop.
- The explanations on evolution were too difficult to comprehend.
- The workshop did not address the concerns and needs of the teachers or accommodate their different levels of experience.

In my study I focused on the last concern.

1.7 AIM OF THE STUDY

The aim of the study was to better understand the needs and concerns of the *Life Sciences* teachers who would have to teach evolution in 2008. The information would support recommendations to the in-service providers about workshops which are likely to be more effective in preparing teachers to teach evolution.

1.8 RESEARCH QUESTIONS

The following research questions were used to guide the research.

- What were *Life Sciences* teachers' concerns and needs regarding having to teach evolution to Grade 12s in 2008, as part of a new curriculum?
- To what extent did teachers who had to teach evolution understand the fundamental evolution concepts they were required to teach?

1.9 CONCLUDING REMARKS

The purpose of this chapter has been to provide a strong argument motivating the study, grounded on a literature review to back up the claims made. The theoretical framework (i.e. the stages of concern) used to understand the teachers' concerns and needs and ideas on the importance of subject matter knowledge will be discussed on the next chapter.