CHAPTER 1

THE CONTEXT OF THE STUDY AND EXPLANATION OF THE RESEARCH

This study is about investigating the pedagogical content knowledge (PCK) of *Life Sciences'* teachers who were to teach evolution for the first time in Grade 12. Evolution is one the new topics that were added to the new *Life Sciences* curriculum. PCK is a concept first introduced by Shulman (1986) where he indicates that teachers need more than just subject matter knowledge to teach particular content. In this study Schulman's PCK categories were used as a basis but have been modified to five categories. To collect data seven types of activity-based questionnaires were administered to two groups of teachers ($n_{1=}$ 40 & n_2= 39) attending workshops on the teaching of evolution.

This chapter gives the context of the study as well as giving the details the research problem.

1.1 CONTEXT OF THE STUDY

1.1.1 The new school curriculum in South Africa

The year 2008 saw the complete implementation of the new curriculum in South African schools, with the new curriculum being implemented for the first time in Grade 12 of the Further Education and Training band (which includes the last three grade levels, 10, 11 & 12). The new curriculum requires teachers to change their classroom practices in nine ways (Sanders & Kasalu, 2004), and has also seen the inclusion of some new content. One of the new topics in the *Life Sciences* curriculum is "evolution", which was taught for the first time in Grade 12 in 2008.

1.1.2 Inclusion of evolution in the *Life Sciences* curriculum

Even though evolution is a new topic in Grade 12, some of its aspects have been part of the Grade 7 to 9 *Natural Sciences* curriculum since the curriculum was revised in 2004. These are aspects such as variation, fossils, mass extinction and natural selection. In Grade 7 *Social Sciences,* a whole chapter in most textbooks deals with human evolution. Although evolution is not an entirely new topic in South African high schools, it did not seem to generate much concerns or controversy among teachers or parents; probably because it was not externally examinable therefore teachers probably left it out. 2008 was only when it was included as part of an externally examinable curriculum, where it makes up 25% of the final matriculation examination, and concerns about lack of knowledge and beliefs started to emerge (Sanders & Ngxola (2009). The evolution content outlined in the *Life Sciences* National Curriculum Statement is elaborated upon in the Grade 12 examination guideline document (Department of Education, 2008a) which is summarized in Table 1.

This study was conducted in 2008, when the Grade 12 teachers were covering the content spelled out in Table 1. However, even before its full implementation in 2008, the *Life Sciences* curriculum had already been revised (Department of Education, 2007) and evolution teaching permeated down to

Grade 10 and Grade 11, starting from 2009 in Grade 10, 2010 in Grade 11 and a revised Grade 12 curriculum will be implemented in 2011. See Appendix A for the revised curriculum. Subsequent to that there was another revision of the curriculum called Curriculum and Assessment Policy Statement (CAPS) which will be fully implemented by 2014 (Department of Basic Education, 2011). This revision is, however, not relevant to my study.

Table 1: Summary of evolution content to be covered in Grade 12 *Life Sciences* (based on the Grade 12 examination guidelines, for 2008. Department of Education, 2008a)

Content		Elaboration
Early theories of evolution	Introduction	Nature of science; distinguish between fact, hypothesis, theory, model, law. Purpose of life; diversity; meiosis, mutation, reproduction; evolution & biological evolution
	Early theories	Lamarck and Darwin theories
Explanation of evolution in terms of current knowledge	Introduction	• Current knowledge supports Darwin's ideas
	Variation as an explanation to evolution	• Phenotypic variation a result of genetic variation • Sources of variation (meiosis, mutation, reproduction) • Inbreeding & outbreeding • Explain variation using micro-evolution, speciation, macro-evolution
	Geological time scale	• Need for geological time scale • Structure of the scale • Eras divided into periods • Major events
	Evidence for evolution	• Paleontology • Comparative embryology • Comparative anatomy • Comparative biochemistry • Biogeography
	Mass extinction	• Definition of mass extinction • Mass extinctions in periods of earth's history (five major mass extinctions) • Early theories, extraterrestrial theories
Human origins	Our place in the animal kingdom	• Interpret phylogenetic tree
	Characteristics we share with other primates	• Opposable thumb, bare finger tips, long arms, freely rotating arms • Stereotypic vision, eyes with cones • Large brain compared to body mass, olfactory brain centres diminished • Few offspring
	Characteristics that make us different from other primates	• Bipedalism • Flat face • Smaller canines • Jaws with teeth on gentle curve • Large brain • Artificial language
	Trends in human evolution	• Changes in structure that characterize human evolution
	Search for the cradle of humankind	• Explain anthropology, paleontology and archaeology • Cradle of humankind in Southern Africa, East Africa & Central Africa
Arguments against evolution		• Age of the earth • Probability of forming organic molecules by chance • The tendency towards disorderliness • Gaps in fossil record

1.2 THE IMPORTANCE OF TEACHING EVOLUTION

In order for the biology teachers to effectively teach a topic as tough as evolution (due to lack of knowledge and numerous misconceptions) they need to have an understanding of the importance of evolution as discussed in the next three subsections. The teaching of evolution makes learners to be aware of the "powerful contemporary problem-solving tool" that biological evolution is (Scharmann, 2005:13). Teaching them the evolutionary theory will also allow learners to experience and understand the scientific principles and processes underpinning the nature of science and to logically and thoughtfully analyze scientific evidence (Cavallo & McCall, 2008).

"*Charles Darwin had a big idea, arguably the most powerful idea ever*" (Dawkins, 2008:1).

There are three reasons why evolution is important in biology:

1.2.1 Evolution is a unifying concept

The scientific community worldwide has accepted that evolution is one of the most powerful unifying concepts in biology (Bishop & Anderson, 1990; Clough, 1994; National Association of Biology Teachers, 1995; Rutledge & Warden, 2000; Rutledge & Mitchell, 2002; National Science Teachers' Association, 2004). The concept of slow changes in populations over time provides a "golden thread" (Parry, 2008) that links biology disciplines such as palaeontology, biogeography, physiology, ecology, systematic, embryology, genetics and cytology (Farber, 2003; Cavallo & McCall, 2008). Dobzhansky (1973:129) says that without evolution "*biology is a pile of sundry facts ... making no meaningful picture as a whole*". Many textbook authors also do not treat evolution as an isolated topic, but use it as a theme in different topics and disciplines, as is the case in some modern tertiary textbooks like the biology textbook by Raven, Johnson, Losos and Singer (2005). Haury (1996) says that because evolution is a unifying concept, it can be used across all grades to align the biology curriculum. Evolution is also a unifying concept in science in general because disciplines like physics, astronomy, geology, anthropology, biology and geochronology all support the premise that change through time has occurred (National Science Teachers' Association, 2004).

1.2.2 Evolution is a powerful explanatory tool

Dobzhansky asserted forty years ago that "*nothing in biology makes sense except in the light of evolution"* (Dobzhansky, 1973:125). As an explanatory tool, evolution can be used to answer "why", "what" and "how" questions concerning the diversity of life. Farber (2003) and the National Academy of Sciences (2008) explain that understanding biological evolution (in particular that species have genetic variations) allows you to understand other matters.

- **The diversity of life**. The diversity of life has come about due to organisms adapting to environments as a result of natural selection. The environment does not cause the organisms to evolve, but provides challenges which the organisms will respond to by adapting because of the genetic variations they possess (Dobzhansky, 1973). Adapting to different environmental conditions, the availability of different food types and developing different

mechanisms for survival has resulted in a wide diversity of different types of living organisms.

- **Why some organisms that look alike may not be related and why some that look different may actually be closely related**. Genetic variations that occur within populations' gene pools, allow populations that have a common ancestor to adapt and evolve into different species which diverge from their common ancestor. Divergence could be a result of selection pressures offered by different environments resulting in related species adapting and becoming different (Raven *et al*., 2005; Campbell, Reece, Urry, Cain, Wasserman, Minorsky & Jackson, 2008). For an example, the forelimbs of different classes of vertebrates are homologous structures with different appearances and functions, although their bones show similarities, suggesting that they are descendents of a common ancestor (Raven, *et al.,* 2005). On the other hand, because of common environments, different animals may become superficially similar because of adapting to similar environmental demands, resulting in convergent evolution, e.g. the streamlined body shape of sharks (fish) and dolphins (mammals) is an adaptation to their aquatic life style (Raven *et al*., 2005).
- **Why the DNA building blocks in different organisms are the same**. With the exception of viruses, the basic structure of the DNA molecule is the same for all organisms, consisting of the same four nucleotide types; adenine, guanine, thymine and cytosine (Campbell *et al.,* 2008). This suggests that all organisms may have a common ancestor. It is the number and sequencing of these nucleotides that make the DNA of each organism unique, coding for different proteins which result in variation. Closely related organisms have DNA which is more similar than distantly related organisms, e.g. humans and chimpanzees have only five differences out of 250 nucleotides found in their DNA structure encoding for the hormone leptin (National Academy of Sciences, 2008).
- **Why so many chemical pathways and life processes are the same in different organisms**. "*The DNA evidence suggests that the basic mechanisms controlling biological form … have been conserved with little modification*" (National Academy of Sciences, 2008:32). This may explain why many life processes, e.g. cell division and respiration, are similar in different organisms. "*At the level of DNA, some genes that control the production of biochemicals or chemical reactions that are essential for life show little variation across species"* even those that are distantly related (National Academy of Sciences, 2008:6).
- **Why organisms with highly specialized structures are able to live in hostile environments**. *"Individuals in populations exhibit variations in their heritable traits, and those with variations better suited to their environments tend to produce more offspring"* (Campbell *et al.,* 2008:460). This ultimately results in a population with more individuals with the advantageous genes resulting in the population evolving and becoming better suited for its environment, no matter how harsh it is (Raven *et al.,* 2005).
- **Why some organisms have structures that are of no particular use (vestigial structures).** These vestigial structures are *"remnants of structures that served important functions in the organisms' ancestors"* (Campbell *et al.,* 2008:448). For an example, the pelvic bone in the baleen whale is a remnant from when whales had a complete and functional pelvic girdle which has degenerated because it is no longer used.

1.2.3 Evolution is a contemporary problem-solving tool

For centuries human beings have been mimicking the process of natural selection by using artificial selection to improve their crops and animals (Pigliucci, 2005). Scientists also use the mechanisms of evolution (natural selection, DNA and mutations) to study conservation and management of environments (Pigliucci, 2005).The theory of evolution has become *"the foundation of disease tracking and of the identification of species in medical, pharmacological, or conservation settings"* (Bull & Wichman, 2001:1). The similarities between organisms are used in modern biomedical research to study organisms to understand "*biological processes critical to human kind"* (National Academy of Sciences, 2008:31), which can be used to solve problems facing humans. By applying their understanding of genetics (DNA), natural selection and common ancestry, health researchers are able to develop vaccines and antibiotics, and can deal with antibiotic resistance of bacteria and HIV-resistance (Wuerth, 2004; Scharmann, 2005). The National Academy of Sciences (2008) indicates that to solve the SARS (severe acute respiratory syndrome) pandemic, scientists needed an understanding of evolution (that organisms change over time) to identify the SARS virus.
"Our goal as biology teachers should be that students understand evolutionary theory to be the most powerful contemporary problem-solving tool at the disposal of the biologist" (Scharmann, 2005:13). Evolutionary theory can be used to solve biomedical problems, make predictions and to explain phenomena (Scharmann, 2005).

1.3 THE PROBLEMS THAT MOTIVATED THE STUDY

"*Biology teachers are … not teaching evolution effectively- whether they are creationists themselves, or because they are experiencing pressure from communities, or simply because they are not confident about their knowledge"* (Wiles & Branch, 2008:6).

In the United States of America the teaching of evolution is often influenced by "personal views, and parental, student, and administrative pressure" (Gerking, 2003:8). "*Evolution has been criticized as ungodly and detrimental to Christian faith"* (Osif, 1997:552). Trani (2004) indicates that teachers do not teach evolution because of their strong religious convictions which are directly linked to their lack of understanding of the nature of science and the evolutionary theory. According to Antolin & Herbers (2001), the controversy around the teaching of evolution rests on amongst other things, scientific illiteracy and religious values, where some creationists use widely spread misconceptions about evolution to discredit and therefore remove it from the curriculum, school board policies and science teaching standards. This study was motivated by a number of problems concerning the teaching of evolution.

1.3.1 The controversial nature of evolution teaching

Evolution is a controversial topic to teach. While the scientific community accepts the role of evolution, the general public seems to hold a different view (Rutledge & Warden, 2000; Matthews 2001; Trani, 2004; Stears, 2006). Some communities and teachers see the introduction of evolution as a way of nullifying the legitimacy of their religious beliefs (Rutledge & Mitchell, 2002). In Kansas for

an example, some education board members suggested that a person could not believe in God and evolution, insinuating that evolution is against religion (Hemenway, 1999). According to Meadows, Doster and Jackson (2000), some American parents refuse to allow their children to be taught evolution as it undermines their world view. The inclusion of evolution in the school curriculum in America has resulted in numerous court battles, between parents, some religious groups, and education authorities (Moore, 2003).

Teachers find themselves in the middle of these battles, because they want to teach and deepen learners' understanding of evolution while at the same time they do not want to undermine the values of the learners, their parents or communities (Osif, 1997; Meadows *et al,* 2000). Moore and Kraemer (2005) report that there is an increase (29% increase) in the number of teachers who said that they were pressurised by parents and administrators to avoid teaching evolution. Thirty percent of teachers in the survey conducted by NSTA indicated that they were pushed to de-emphasise or even omit evolution form the curriculum (National Science Teachers Association, 2005). This pressure, they say comes from parents and students. In the very same study 69% reported that the students pressurise them to teach creationism. One American author pointed out that "*in some parts of the country, teachers may fear having to justify and defend the teaching of evolution to their communities"* (Wuerth, 2004:109). A consequence of this problem is that many teachers do not teach evolution appropriately, or simply omit it or even include creationist concepts in the evolution curriculum.

Teachers' personal views on a topic or subject matter will heavily influence or determine how the topic is treated in the classroom. In teaching a topic like evolution, teachers are sometimes challenged by their own personal beliefs which are in conflict with their own understanding of the theory of evolution. In a study conducted by Aguillard in Louisiana, 23% of the teachers placed little or no emphasis on teaching evolution (Aguillard, 1999). In his study Trani (2004) indicates that teachers with strong religious convictions show a low acceptance of the theory of evolution than those with little religious convictions, which resulted in them not presenting evolution in their classrooms. Scott (1999:8) indicates that "*a teacher who does not accept evolution is unlikely to teach it, or will mislead students"*. In one study, Rutledge and Mitchell (2002) found that there was a relationship between teachers' acceptance of evolution and their emphasis on evolution when they teach. Several similar studies conducted across America gave similar results (Alles, 1999; Weld & McNew, 1999; Rutledge & Warden, 2000; Rutledge & Mitchell, 2002).

In South Africa there has been little research done on the introduction of evolution in the South African high school curriculum because the topic was only being introduced in 2008. However, there are debates going on about the inclusion of evolution in high school biology (Science in Africa, 2003; Dempster & Hugo, 2006). Alistair Houston-McMillan writes in Science in Africa that the evolutionary theory as an explanation of "human origin" is no longer valid and is not necessary to be included in the curriculum (Science in Africa, 2003). We can predict that many of the problems that occurred in overseas countries will be experienced in South Africa, from people who think that evolution threatens their religious beliefs. Already one staunch creationist has been cited in Science in Africa (2003:2) as saying "*I cannot see why it should be introduced at school. It will cause confusion. It's a theory, a belief that is contrary to 75% of the belief systems of the people in this country".* In one study looking at the concerns of 30 South African *Life Sciences* teachers about teaching

evolution, there were 15 comments relating to teachers' concerns about dealing with the controversial nature of the topic (Ngxola & Sanders, 2008). A teacher in one of the Gauteng schools has been reported to be teaching creationism instead of evolution, reading from the book of Genesis, saying that that is the correct version of what actually happened (Hendrik, 2009). One teacher at a teacher training conference, was quoted as saying that evolution attacks God's creation, while another one thought that it should be voluntary to teach "*because it is not suitable for people who believe in God*" (Mail & Guardian, 2007). From the same conference some black teachers felt that "*evolution was a racist theory*" (Mail & Guardian, 2007).

1.3.2 Teachers' inadequate background knowledge

In order to be an effective science teacher, teachers need to possess, amongst other things, a good command of the subject matter knowledge (Shulman, 1986). They must know the structure of the subject which includes the substantive and syntactic structures (Schwabb, 1978). To make curricular decisions, teachers must master, in sufficient detail, the science content (substantive) which they are expected to teach (Rutledge & Mitchell, 2002). With regards to the teaching of the evolutionary theory they not only need to master the content, but they must also be able to explain to learners why evolution is a unifying concept, a problem-solving and an explanatory tool in biology. They must be able to draw on expertise in their content knowledge in order to generate new explanations in the process of teaching (Shulman, 1986). They also must understand (the syntactic) how scientific facts and theories are arrived at in order to dispel the misconceptions especially in evolution.

Teachers who do not have a good understanding of a topic or subject are not likely to teach it in an appropriate and effective way. Upon reviewing some studies on the teaching of evolution in America, Wuerth (2004) claims that teachers' own lack of knowledge about evolution leads to de-emphasis of evolution in their classrooms.

Stears (2006) claims that most teachers in South African high schools have little or no formal education in the principles and mechanism of evolution, and the results of her study indicate that some South African teachers have poor knowledge of evolutionary theory. Two studies in South Africa report that some South African teachers recognise that they have inadequate knowledge background to teach evolution (Stears, 2006; Ngxola & Sanders, 2008). Eleven of the 30 teachers in the study by Ngxola and Sanders (2008) were concerned about the inadequacy of their own content knowledge, and eight were unsure about what to teach. Furthermore, about six of the eight teachers in my cluster[1] have the same concern. Recently I was called to teach evolution to the Grade 12 *Life Sciences* learners in one of the schools in Gauteng, just a few days before sitting for their final matric exam, because they were not taught as the teacher "does not understand evolution".

[1] A "cluster" refers to a group of South African schools in a district which have been selected according to geographical proximity to promote cooperative development of teachers.

1.3.3 Inadequacy of teacher training by the Department of Education

The problem of teachers' lack of knowledge is compounded by the inadequate training that the teachers received when the new curriculum was introduced. According to Makgoba (1999) and Ngxola and Sanders (2008), teachers have criticized the workshops run by government facilitators as "inadequate" saying that the facilitators themselves seemed not to understand the issues. The author was also part of the teacher training workshop for the implementation of the new curriculum in FET Life Sciences. Training was done mostly on the approach to teaching the new curriculum. Emphasis was laid mostly on the learning outcomes, in particular learning outcome 3 (Life Sciences, Technology, Environment and Society) addressing indigenous knowledge systems, lesson planning and assessment. Evolution as new content was not tackled at all. Only a one-day training workshop for evolution was conducted in Gauteng, prior to the teaching of evolution.

Appropriate interventions of different kinds must be provided to the implementers of change if the change efforts are to be successful (Hall & Hord, 2006). "*To promote successful implementation of the new curriculum requires adequate and proper in-service training support and the provision of suitable teaching and learning resources*" (Matimolane, 2004, p. 6).

1.3.4 Teachers have several other concerns about having to teach evolution

In addition to teachers' concerns about the controversy and their poor knowledge about evolution, teachers have other concerns:

- Different textbooks present evolution concepts in a different order and this causes confusion in how to approach the teaching of evolution according to some teachers from my cluster.
- Seven of the 30 teachers in one South African study were worried about lack of teaching resources for teaching evolution (Ngxola & Sanders, 2008) - a concern also identified in one study in America (Wuerth, 2004).
- Four of the 30 teachers in the same study were concerned about how to approach the teaching of evolution (Ngxola & Sanders, 2008).

Matimolane (2004) indicates that in order for teachers to be confident to try out new ideas they need a strong grounding in the subject matter knowledge. Thus the department of education needs to provide "for upgrading of serving science teachers' subject content knowledge" (Matimolane, 2004:7).

1.4 AIM OF THE STUDY

Shulman (1986:8) asked "*how do teachers prepare to teach something they never learned previously"?* The aim of this study is to look at the nature and extent of the pedagogical content knowledge of a group of South African *Life Sciences* teachers having to teach evolution for the first time.

Sanders (1993:1) says the ultimate purpose for science education research "*should be to apply the research in the classroom situation to improve the effectiveness of education by finding out about problems which prevent effective teaching and learning"*. Identifying gaps in teachers' pedagogical content knowledge is important for assisting teacher trainers and curriculum designers to develop support materials that will help support these teachers in gaining access to an understanding about the knowledge needed to effectively teach evolution.

In order to limit the scope of the study so that it is suitable for a Masters research project , I am going to focus only on teachers' PCK, involving only teachers' knowledge. I will not look at how they transform and apply it in the classroom.

1.5 RESEARCH QUESTIONS

In order to explore the PCK of Grade 12 *Life Sciences* teachers having to teach evolution for the first time, the study will attempt to answer the following questions:

- **The main research question**: What was the nature and extent of the pedagogical content knowledge of *Life Sciences* teachers teaching evolution for the first time in South African high schools?
- **Sub-questions:**
  - What was the extent of the teachers' subject matter knowledge for teaching evolution?
  - What did the teachers know about likely learning and teaching difficulties they could anticipate when teaching evolution?
  - What common misconceptions associated with evolution did the teachers know about?
  - What teaching strategies did the teachers know about how to increase learners' understanding of evolution?
  - What was the teachers' curricular knowledge for teaching evolution?

1.6 CONCLUDING REMARKS

This chapter explains the introduction of evolution as new content in the Grade 12 *Life Sciences*. It briefly explores the importance of including this important biological concept in the curriculum. It also highlights the controversy surrounding the teaching of this topic in other countries, especially the U.S of America. Issues about relating to the teachers' knowledge about this topic are raised, in this chapter. The next chapter explores the pedagogical content knowledge of teachers as a framework to this study.