CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents an analysis of the findings of the study and focuses discussion on the results obtained from two samples of *Life Sciences* teachers who were to teach evolution for the first time in Grade 12 in 2008. The information gathered from the questionnaires given to the teachers was analysed to get a clear understanding of the nature and extent of pedagogical content knowledge these teachers had for teaching evolution. Analysis of these results is important as it highlighted gaps in the teachers' pedagogical content knowledge for teaching evolution, which could be used to inform curriculum developers of what kind of support materials to develop to assist teachers to gain access to an understanding of how to teach evolution effectively. The results could also assist teacher trainers to address the identified gaps during the training of teachers because, as indicated by Sanders (1998:1), the aim of science education research "*should be to apply the research in the classroom situation to improve the effectiveness of education*". Before I could answer the research question, I first looked at the demographics of the sample.

4.1 DEMOGRAPHICS OF THE SAMPLE: TEACHER QUALIFICATIONS

Knowledge of content is important for teachers to have confidence in teaching a particular topic. However, Stears (2006:178) claimed that most South African teachers at the time did not have "*formal training in the principles and mechanisms of evolution*", but did not provide supporting data. I therefore started by looking at the qualifications of the teachers in the study, and whether they remembered being taught about evolution in their tertiary studies.

A list of tertiary qualifications ranging from a three-year diploma to Masters degree was given to the teachers to let them indicate which qualifications they had completed at tertiary level. In the same questionnaire, they were also asked to indicate if they remembered being taught evolution during their tertiary education. The sample size for this questionnaire was 75.

The minimum qualification required to teach in the Further Education and Training band (the last three grade levels of basic education, 10, 11, and 12) is a three-year or four-year diploma in education [1](Education Labour Relation Council, 2003). Less than half of the teachers of the teachers (40%) reported having the basic minimum of a three-year or four-year education diploma as their qualification. At the other end of the qualification spectrum, just over a quarter of the teachers (28%) had a postgraduate degree in the form of an Honours degree or a Masters degree. The remainder of the

[1]Diploma: 3-4 year teacher qualification that focuses on getting a person trained and qualified in specific area of education (such as foundation; intermediate; senior or further education phase) and was previously awarded by colleges of education. Degree: 3-4 year qualification traditionally offered at universities and has more theoretical (academic) and less practical basis.

sample (32%) reported having a four-year professional degree or a three-year academic degree coupled with a one-year postgraduate diploma (see Table 6 below).

Table 6: Teachers' qualifications, and whether they remembered learning about evolution at tertiary level (n=75)

Highest qualification	Frequency of responses per qualification	Frequency of teachers' recollection about having learned about evolution at tertiary level	
		Yes	No
Diploma (three-year or four-year)	30 (40%)	6 (20%)	24 (80%)
Three-year degree + one-year postgraduate diploma[1]	12 (16%)	3 (25%)	9 (75%)
Four-year professional degree[2]	12 (16%)	2 (17%)	10 (83%)
Postgraduate degree[3]	21 (28%)	11 (52%)	10 (48%)
Total	**75**	**22 (29%)**	**53 (71%)**

[1] An academic degree with two or more subject specialisations does not qualify one to be a professional teacher and requires an additional postgraduate teaching diploma qualification that focuses mainly on developing practical competence grounded in educational theory.

[2] Teaching-focused degree – an initial qualification for teachers.

[3] An advanced and specialised academic degree, which includes Honours, Masters or Doctoral degrees (Education Labour Relation Council, 2003). The basic requirements for an honours degree is a 1st bachelor's degree or post-graduate certificate in education. The prerequisite to a Masters degree is an Honour's degree whilst the Masters degree is a prerequisite to a doctoral degree.

Although all the teachers in the sample met the requirements for teaching in the Further Education and Training band, this does not necessarily mean that they had learned about evolution at tertiary level. Just over a quarter of the 75 teachers who answered the questionnaire (29%) indicated that they remembered studying evolution during their tertiary education studies. Of the thirty teachers who have a three-year or four-year diploma only 6 (20%) indicated that they remembered being taught evolution at tertiary level. Only two teachers (17% of the 12) who held a four-year professional degree indicated that they had learnt about evolution during their tertiary education. About 52% of the teachers holding a postgraduate degree indicated that they had studied evolution in their tertiary studies, suggesting that there is quite a number of teachers to whom evolution is not a completely new concept. The majority of the teachers in the sample (71%) either had not formally studied evolution at tertiary level or did not remember doing so. The data is consistent with Stears' claims in 2006 that most South African teachers had no formal training in evolution studies. In 2008 this was a cause for concern as it suggested that most of this sample of teachers who were about to teach evolution for the first time may not have had the necessary background knowledge to teach the topic. However, it could be argued that although most of the teachers had no formal training about evolution, they might have learnt about it in other ways like reading, watching programmes on television, or even visiting museums such as the heritage site at Maropeng. However, this aspect was not determined in this study. The implication is that about three-quarters of the sample still had a significant amount of preparation to do before they had adequate knowledge to teach evolution.

ANSWERING THE RESEARCH QUESTIONS

The data and the discussions that follow are an attempt to answer the following research question:

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?

This study uses the five-category model of PCK spelled out by Sanders (2008), as discussed in Chapter 2, pages 14-15, to answer the main research question of this study. Five sub-questions were posed to address the five categories of pedagogical content knowledge associated with the teaching of evolution.

4.2 SUBJECT MATTER KNOWLEDGE

The first of the five aspects of pedagogical content knowledge is subject matter knowledge. In order for teachers to be effective and foster conceptual understanding they are expected to have a good command of the subject matter knowledge (Shulman, 1986; Feiman-Nemser & Parker, 1990). Rutledge and Warden (2000) point out that biology teachers need this thorough knowledge of the theory of evolution to make informed and professionally sound instructional and curricular decisions. The first sub-question in this study targeted teachers' subject matter knowledge .

Research sub-question 1: What is the extent of the teachers' subject matter knowledge about evolution?

Three activity-based questionnaires used in the workshop supplied data to answer this research question, and each is discussed in one of the following sub-sections.

4.2.1 Teachers' own knowledge estimates about basic concepts to be taught in evolution

Activity-based questionnaire 2 (see Appendix C4) consisted of a table listing all the evolution topics that were required to be taught, which were derived from those listed in the examination guidelines for Life Sciences Grade 12 (Department of Education, 2008a). The instrument asked *"Do you think you know enough about evolution to teach it?"*. Teachers rated their knowledge of each topic as "excellent", "good", "satisfactory" or " poor". The aim of this activity was to raise the teachers' self-awareness of their knowledge (or lack thereof) regarding evolution so that they could identify possible shortcomings and take the necessary action to address these.

Table 7 on the next page summarises the self-rated knowledge about the evolution concepts the teachers would be required to teach. One teacher arrived late for the workshop so 78 teachers responded to this questionnaire. The data shows the number of teachers in each category per topic expressed in percentages. My interpretation of the knowledge levels as they appear in the table is:

- *Poor* – means teachers have little or no knowledge about the evolution and therefore probably need additional training on evolution content.
- *Satisfactory* – means that the teachers might have sufficient knowledge about evolution that they think they can teach it.
- *Good* – means that the teachers think that they have enough knowledge about evolution that they can teach it well.
- *Excellent* – suggests that the teachers have more than adequate knowledge about the evolution content and therefore feel very confident that they can teach it at a very high standard.

Table 7: Teachers' knowledge estimates about basic concepts of evolution (n =78)

Evolution topics to be taught in Grade 12	No answer (frequency)	Percentage			
		Excellent	Good	Satisfactory	Poor
Introduction to evolution					
Nature of science (differences between fact, hypothesis, theory, model & law)	1	9	21	42	27
Definitions (evolution, archaeology, palaeontology, anthropology)	1	4	26	41	28
Early theories of evolution					
Lamarck's theories of evolution		8	19	31	42
Darwin's theory of evolution by natural selection		12	24	45	19
The difference between Lamarck's and Darwin's theories		6	21	31	42
Variation as an explanation of evolution					
Phenotypic variation as a result of genetic variation.	1	13	31	42	13
Sources of variation (mutation, meiosis, reproduction)		18	41	28	13
Inbreeding and outbreeding		12	32	33	23
Explain variation using micro-evolution, speciation, macro-evolution)		9	22	30	39
Evidence for evolution					
Palaeontology (study of fossils)		9	21	35	35
Comparative embryology		6	17	41	36
Comparative anatomy (homologous & analogous structures)		4	21	42	33
Comparative biochemistry		4	13	33	50
Biogeography		4	13	33	50
The geological time scale					
Need for geological time scale	1	4	19	30	46
Structure of geological time scale		6	17	27	50
Eras divided into periods		6	13	31	50
Major events in the eras of geological time scale		6	13	28	53
Popular theories of mass extinction					
Definition of mass extinction	1	11	22	36	30
Factors contributing to mass extinction in periods of Earth's history (continental drift, ice age, volcanic activity, heating & cooling atmosphere and disease)		12	24	41	23
Extra-terrestrial theories possibly causing extinctions (explosion of star, meteor collision, comets)	2	6	16	41	35
Cradle of humankind					
Where are humans thought to have evolved	2	8	27	41	22
Evolution of hominids		5	21	37	37
Arguments against evolution	7	2	14	47	30

The highlighted cells indicate the knowledge rating category with the highest number of responses.

The following two graphs provide a visual summary of the extent of the teachers' self-rated knowledge about the evolution concepts they were required to teach. In the first graph, I have pulled out the eleven topics (out of the twenty-four listed in Table in the previous page) where the majority response from the teachers indicated that they had "poor" knowledge, except for the last two, which were equal for both "poor" and "satisfactory" knowledge.

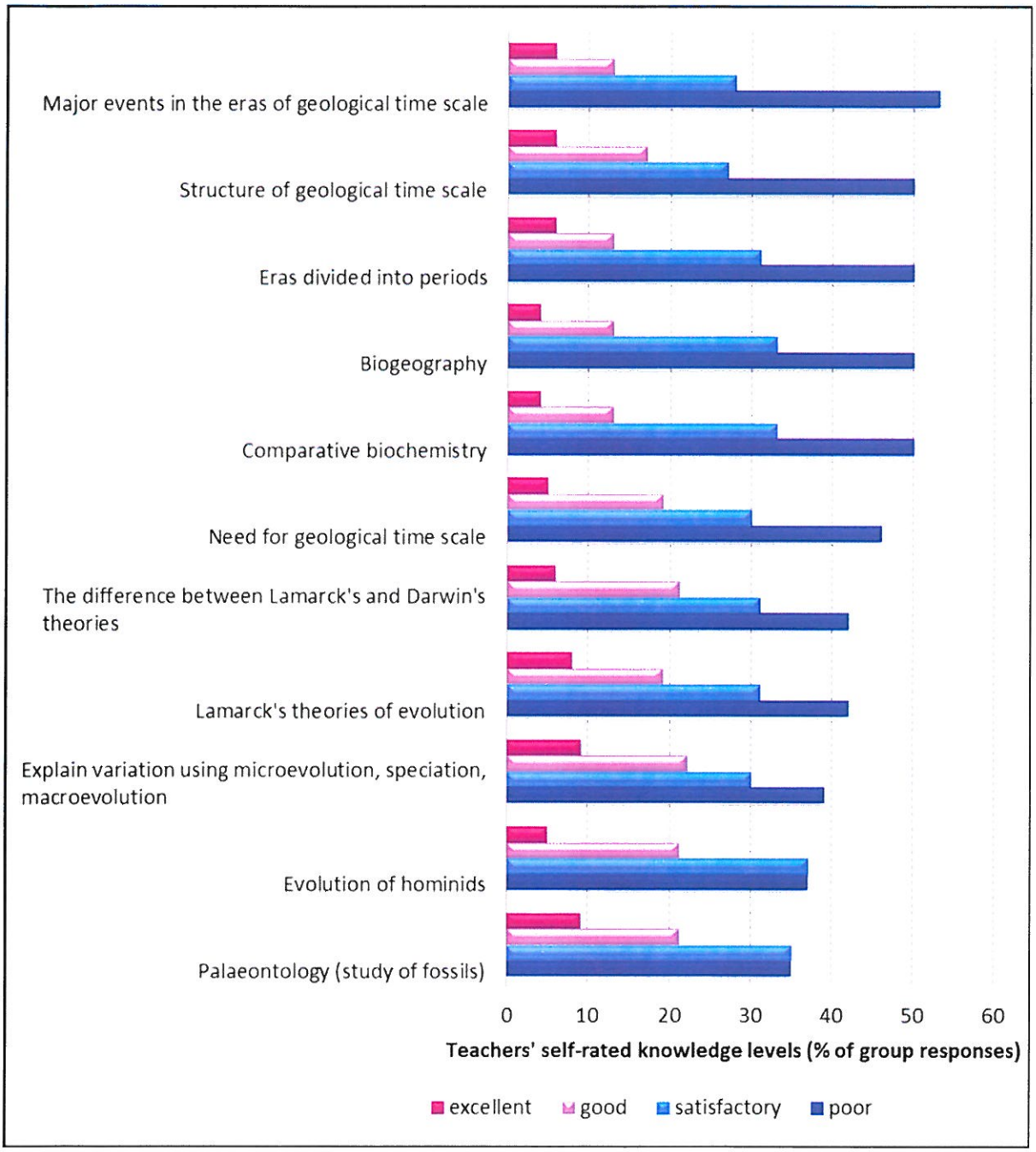

Figure 5: Topics where "poor" was the most frequent self-rated knowledge level

In the eleven evolution-related topics shown in Figure 5 between 35% and 50% of the teachers acknowledged that their knowledge regarding these topics was "poor". The topic in which most of the teachers (53%) indicated that they have poor knowledge is the "major events in the eras of geological

time scale". The areas that may be of most concern to teacher trainers are topics where at least half of the teachers (50%) indicated that their knowledge was "poor". This includes comparative biochemistry, biogeography, structure of the geological time scale, eras divided into periods, and major events in the eras of the geological time scale. Between 42% and 46% of the teachers indicated that their knowledge of "Lamarck's theory of evolution", "the difference between Darwin and Lamarck's theories" and "the need for geological time scale" was poor. Teachers indicated "satisfactory" and "poor" knowledge equally regarding the topics "evolution of hominids" (37%) and "palaeontology (35%). About 30% of the teachers believed that their knowledge regarding seven topics was "satisfactory".

Figure 6 (on the next page) shows the eleven topics for which the most frequent responses from the teachers indicated that they thought their knowledge of these topics was at least "satisfactory".

For nine of these topics about 40% of the teachers selected the "satisfactory" category. My interpretation of "satisfactory" is that the teacher might have sufficient knowledge about evolution that they think they can teach it. That these teachers thought that their knowledge was satisfactory may be attributed to a range of factors. They may have been familiar with some of the topics, possibly having seen evolution documentaries on television before. Another reason could be that they may have learnt about them in their tertiary studies. A third possible explanation could be that they might already have started preparing to teach evolution.

The only topic of the 24 listed where the majority of the teachers indicated that their knowledge level was "good" was "sources of variation" (40% of the teachers stating this). This may be because the topics listed (mutation, reproduction and meiosis) are topics that have long been in the *Life Sciences* curriculum and the teachers might have taught them before.

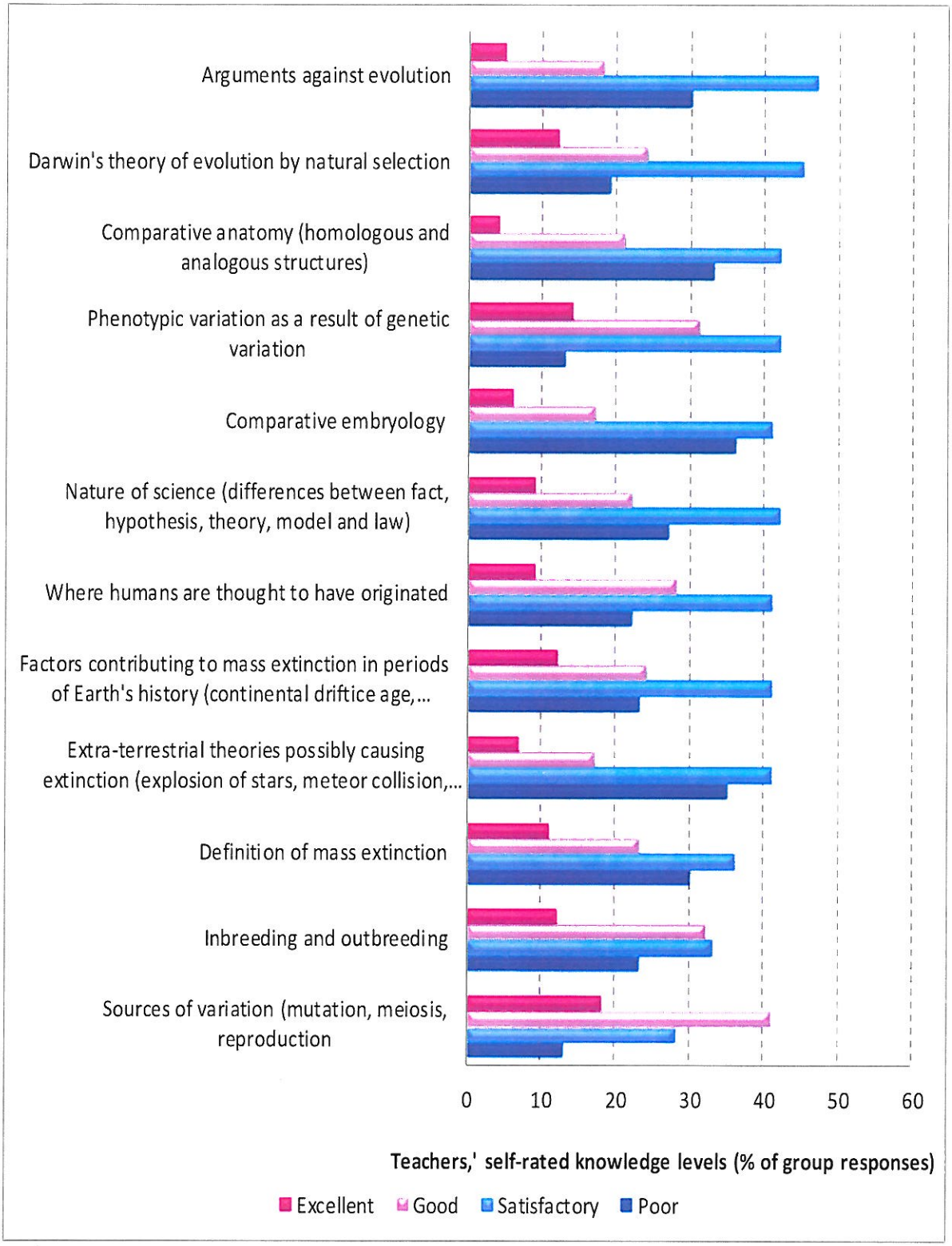

Figure 6: Topics where "satisfactory" was the most frequent self-rated knowledge level

I have further analysed each teacher's self-rated knowledge about the teaching of evolution by dividing the results into the two workshops sub-samples. Table 8 on the next page provides a summary of these results. Each teacher's overall self-rated knowledge has been classified as

"excellent", "good", "satisfactory" or "poor", based on the most frequent self-rating category of each teacher. For example, of the four knowledge levels, if a teacher rated their knowledge of most topics as "excellent", that teacher's overall self-rated knowledge level was categorised as "excellent". For example, the overall rating of teacher #3.S was classified as "good" because this is where she rated her knowledge of 11 of the 24 topics, and frequencies for the other categories were lower than 11.

Table 8: Summary of the categories of teachers' self-rated content knowledge (n=78)

Teachers' knowledge estimates of the basic concepts of evolution	SAASTE (n=38)	NAPTOSA (n=40)	Total (n=78)
Excellent	3 (8%)	3 (8%)	6 (8%)
Good	6 (16%)	8 (20%)	14 (18%)
Satisfactory	14 (37%)	12 (30%)	26 (33%)
Poor	15 (40%)	17 (43%)	32 (41%)

The data indicate that only 8% of the teachers achieved an overall rating of "excellent", based on their estimates of their knowledge of the concepts they were required to teach in both the teacher groups respectively. I categorised fourteen (18%) of the teachers as having overall "good" knowledge, six from SAASTE and eight from the NAPTOSA group. The knowledge of the majority of the teachers (41%) was categorised as "poor". This is a cause for concern as the teachers were supposed to have started teaching evolution at the beginning of the third term (mid-July), and the NAPTOSA data was collected in August whilst the SAASTE data was collected in the first week of July. Just at a time when they were supposed to have started teaching evolution, 43% of the NAPTOSA teachers had an overall knowledge level of "poor". There was not much of a difference in term of the numbers of teachers' self-rated estimates.

4.2.2 Teachers' explanations of evolution

Based on their self-rated knowledge reported in the previous section, 45% of the teachers had indicated that their knowledge of Darwin's theory of evolution by natural selection was "satisfactory", 24% claimed that their knowledge was "good" and 12% indicated that they had "excellent" knowledge about this topic (see Table 7 on page 43). According to Wallace and Louden (2000), what teachers say they know is not always accurate, maybe because they feel embarrassed to admit that they do not know. To find out what they actually knew about evolution, two further activity-based questionnaires were used. The first activity-based questionnaire (see Appendix C2) asked them to *"Explain what you think is meant by evolution in biology"*.

If teachers are to teach a topic like evolution effectively they need to master the content in sufficient detail; this includes definitions and explanations of mechanisms involved. The Grade 12 examination guidelines (National Department of Education, 2008a) outline the evolution content that South African teachers are expected to teach, which includes definitions of several concepts that are related to evolution, including the definition of evolution itself. When analysing the responses to the question posed above, I realised that instead of explaining what is meant by evolution, most teachers just gave a definition of evolution but did not explain the mechanism, as was the case in a contemporaneous study reported by Ngxola (2012). In answering the question that asked for an **explanation**, I expected

a definition (what) and explanation (how). However, most of the teachers responded to the "what" and not the "how".

According to Moran (1993), scientists and the public seem to be confused about the accurate meaning of evolution. He adds that scientists themselves cannot agree about the correct meaning of biological evolution. However, Ngxola (2012) went to great lengths to provide a validated explanation for evolution. I therefore used the explanation for evolution compiled by Ngxola to judge the correctness of the teachers' explanations. She (Ngxola) listed the definitions from various biology dictionaries and a range of science and science education references, and asked for comments from two evolution "experts" on the accuracy of the definitions. Seven aspects, which defined and explained evolution were extrapolated from these definitions. Three university academics who taught evolution to the Honours students were then asked to face-validate this list of seven points. According to Ngxola (2012:72) to be considered complete and correct, the explanation of evolution had to contain the seven aspects listed below:

- *"**Change in the frequency of traits** in **a population** over **successive generations**, so that the more favourable traits become more established in the population".*
- *This happens because individuals in a population exhibit genetic variation, with some traits being advantageous to the individual.*
- *Individuals better adapted for survival are reproductively more successful (produce more offspring).*
- *Reproductively successful individuals pass their traits (including the favourable traits) on to a greater number of individuals in the next generation.*
- *In this way, the favourable traits become more frequent in the population over successive generations and the population evolves. (**NB. Populations evolve. Individuals do not evolve).***
- *Only genetically-based traits can be passed to future generations*[2].
- *The scale of the change may be small (microevolution) or large (macroevolution).*
  ***Microevolution**: small-scale genetic changes (below species level) in the frequency of alleles in a population, over successive generations.*
  ***Macroevolution**: large-scale genetic changes (at or above species level). This can result in the development of a new species if the original population is split resulting in two populations that are reproductively isolated due to genetic changes.*

Because most teachers gave only a definition of evolution, I decided that just the three essential components of evolution (in the first bullet) would be used as the acceptable explanation for the results of this study, as had been the case with Ngxola (2012):

- change in the frequency of traits

[2] The references used in the explanation of evolution did not consider "cultural evolution" which takes into consideration the behaviours that might be taught to offspring.

- in a population (because it is populations that evolve, not individual organisms)
- over successive generations.

I categorised the responses of 78 teachers into four categories namely: "correct", "have a general idea", "unsatisfactory" and "have no idea". Many of the responses were not well articulated, perhaps because most of the teachers were English second-language speakers. Table 9 provides the explanations of each category and a summary of the teachers' responses.

Table 9: Correctness of teachers' explanations of evolution in biology (n = 78)

Category	Sub-category	SAASTE workshop (n = 38)	NAPTOSA workshop (n =40)	TOTAL (n=78)
Correct (no errors/well worded) ... (n=0)	complete (mentions three criteria)	0	0	0
	incomplete (omits up to two criteria)	0	0	0
Have a general idea. Alludes to at least two aspects, but ... (n = 1)	is incomplete	0	1	1 (1%)
	is poorly worded	0	0	0
	has one error	0	0	0
Unsatisfactory (has vague idea, alludes to only one aspect) and ... (n = 63)	is poorly worded	15	6	21 (33%)
	has one error	8	10	18 (29%)
	has two errors	15	11	26 (41%)
	has more than two errors	6	11	17 (27%)
	is incomplete	28	33	61 (97%)
Have no idea (n = 14)	Incoherent	4	3	7 (50%)
	Off-track	8	4	12 (86%)

It should be noted that the frequencies in the table do not tally with the sample size because some answers contained mistakes that belonged to more than one sub-category

Correct: None of the teachers from the two samples managed to give a complete definition of evolution, in spite of the fact that teaching evolution should have started no later than the beginning of the third term, in July.

Have a general idea: Only one teacher was judged to have a general idea because the teacher's definition had two of the three aspects needed for a complete and correct evolution definition, but was incomplete. The teacher omitted to mention that the change in the gene combination of a population must occur over successive generations. The teacher said:

> *"A gradual change in the gene pool of a population that results from natural and artificial selection pressure"* [#11.N].

Unsatisfactory: Just over 80% of the teachers' explanations (63 of the 78) were judged "unsatisfactory". The explanations were judged as "unsatisfactory" if they were poorly worded, incomplete (containing only one criterion) or contained errors.

- **Poorly worded**: definitions were classified as poorly worded when the explanation was not clear but I could make some sense of what the teacher was trying to say. A third of the teachers' (21 of the 63) explanations were poorly worded. For example:

"Physical or external alternation (sic) of living organisms from one form to another over a long period of time. Gradual change of structure of living organisms to another different class" (#27.N).

"This is a change of phenomena such as plants and animals into something new or similar. This is due to genetical change over time" (#27.S).

- **Incomplete**: In the category "unsatisfactory", definitions were classified as "incomplete" did not allude to more than one of the three criteria, for example:

  "The turning point of humankind (mammals) from generation to generation" (#19.N).

  The "turning point" could mean e change (this could be a language problem). Misconception in this case is that not only humans evolve, but populations of living organisms. From generation to generation could be interpreted as over successive generations.

- **Unsatisfactory with errors**: About 97% of the definitions (61 of the 63) in the unsatisfactory category had one or more errors (see Table 9 on page 49). The misconceptions were mostly to do with the mechanism of evolution (mostly about adaptation) and the origin of species. For example:

  "The natural progression of the genetics of living organisms to adapt to and survive an ever changing environment. The natural selection could include change of appearance or instinctive behaviour" (#4.N)

  The identified error implies that an organism can adapt to a new environment (presumably by changing its phenotype). Phenotypes are determined by genotypes, and genes are fixed for an individual's lifetime so an organism cannot adapt in its lifetime or change because of environmental changes. Hence, evolution is a generation behind, and not forward looking (Freeman & Herron, 2007). Even instinctive behaviours are genetically determined (Futuyma, 2009). The underlined portion should have been "populations of living organisms".

  "A change or developmental change that occurs in animal organisms from one generation to another due to change in environment – occurs from one century to another" (#26.S).

  Developmental changes refer to the changes in the process of an individual's natural growth and occur through its life span. It is an on-going process starting at birth and ending at death. Evolution, on the other hand, involves changes in the frequency of alleles in the gene pool of a population over successive generations. It also does not necessarily take centuries for evolution to occur. Furthermore, it is not only animals that evolve, but also other living organisms including plants. Due to change in the environment implies that changes environment cause morphological changes in the organisms, in other words organisms change because the environment in which they live changes. This type of reasoning is teleological as it implies that that there a goal to be attained, the changes are conscious and deliberate. Natural selection and evolution have no intentions and are not forward looking to any goal. Although some species took millions of years to evolve, it not necessarily the norm that evolution should take centuries and centuries, as is the case with evolution of the HI virus (Freeman & Herron, 2007).

Have no idea: Fourteen explanations were classified in the category "have no idea". These explanations were either unrelated to evolution or did not make any sense. When an explanation contained evolution terminology but did not make any sense, it was classified as "incoherent", e.g.

"The changes in stages through genes, DNA" (#17.N).

An explanation was classified as "off-track" if it had nothing to do with evolution, e.g.

> *"Evolution is about practical activities. Evolution is about linking new knowledge with the existing knowledge"* (#8.S)

Seven explanations were classified as "incoherent" and twelve were classified as "off-track". In some instances, the explanations were both incoherent and off-track, e.g.

> *"The process of change brought about the living styles, environment" (#5.S)*

Several misconceptions were identified in many of the teachers' explanations. Of the 78 teachers' explanations, 60 contained misconceptions (ranging from one to three per response). The misconceptions identified will be discussed in more detail in the next section (4.2.3).

The overall impression is that most teachers who participated in this study did not have the necessary knowledge or understanding of the basic concepts of evolution they were required to teach. This is a cause for concern as according to the Grade 12 examination guidelines (Department of Education, 2008a) the teachers in the NAPTOSA group were supposed to have started teaching the topic, as their workshop took place three weeks into the third term. What is more worrying is that some of the teachers seemed not to be aware of their lack of knowledge of evolution, judging by their self-rated knowledge of what is expected of them to teach evolution. Six teachers (8%) indicated that their knowledge of over twelve evolution topics was "excellent", of whom one indicated "excellent" knowledge in all the 24 topics and another in 22 topics, yet none was able to give a correct explanation of evolution. Nine teachers (12%) rated their knowledge of over ten topics as "good". The data relating to teachers' self-rated knowledge in Table 7 (on page 43) is not supported by the accuracy of data yielded by the teachers' explanation of evolution above.

4.2.3 Teachers' misconceptions about evolution

One of the factors contributing towards the controversy of teaching evolution and the difficulty in learning about evolution is the widely held misconceptions of the public, including learners and some teachers. If not properly addressed, misconceptions tend to interfere with learning (Smith, diSessa & Roschelle, 1994). It is therefore important that teachers know the misconceptions that are associated with scientific concepts they teach, and plan accordingly (Ausubel, Novak & Hanesian, 1978 as cited in Lawson & Worsnop, 1992). The misconceptions associated with evolution may be attributed to incorrect knowledge, a misunderstanding of the nature of science, a lack of understanding of the evolution mechanism, or scientifically incorrect claims perpetuated by some religious organisations (for example in America) trying to dissuade the teaching of evolution.

The second aspect of the data, which allowed me to check whether the teachers' self-rated knowledge was accurate, was looking at their misconceptions. Two sources of information enabled me to identify the misconceptions held by the teachers, the first of which was misconceptions in the teachers' explanations of evolution and the second being the evolution misconception quiz (see Appendix C3).

Misconceptions identified in the evolution explanations

Table 10 shows a summary of the misconceptions held by teachers, which were identified when their explanations of how evolution occurred were analysed.

Table 10: Errors incorporated in the teachers' explanations of evolution (n=78)

Misconception	Frequency
Individual organisms change	37 (47%)
Organisms adapt as a result of environmental changes or food needs	27 (35%)
Evolution explains the origin of life	16 (21%)
Evolution means change of species	11 (14%)
Evolution is when organisms change from one form to another	10 (13%)
Evolution explains the origin of only humans	9 (12%)
Evolution means moving to some end point (from simple to complex)	5 (6%)
Evolution occurs as a result of time (requires centuries to occur)	3 (4%)
Only animals evolve	2 (3%)
Organisms must mutate to evolve	2 (3%)
Organisms evolve in order to survive	1 (1%)
Organisms will die if they do not evolve	1 (1%)
Evolution occurs in stages	1 (1%)

The most frequent misconception in the teachers' definition of evolution, held by almost half of the teachers (47%), was that individual organisms change. Populations evolve not individual organisms. Natural selection acts on individuals, but its results occur in populations (Freeman & Herron, 2004). The second most frequent misconception, held by 35% of the teachers, was that organisms adapt because of environmental change. This misconception is associated with the mechanism of evolution and the incorrect use of the word "adapt". Adaptation has meaning in everyday language that differs from the scientific meaning (Bishop & Anderson, 1990). Scientific adaptation involves those characteristics that individuals already have that allow them to survive changing environmental conditions. Natural selection does not allow organisms to adapt, but favours those organisms that already have the characteristics that enable them to survive. Natural selection is responsible for the evolution of adaptive features (Gregory, 2009). Another frequent misconception, held by 21% of the teachers, is that evolution explains the origin of life. A more detailed discussion of these misconceptions is provided in the next section.

Misconceptions identified from the evolution quiz

Teachers were given an evolution quiz (near the start of the workshop before any evolution content was taught). The purpose was to identify any misconceptions that the teachers may have had. Activity-based questionnaire 4 (see Appendix C3) was a "true" or "false" evolution quiz, which contained twenty misconceptions associated with evolution. The questionnaire asked the teachers to *"indicate whether you consider the following statements to be true or false by circling T or F"* (see Appendix C3). Fourteen of the twenty misconceptions were content related and the other six were associated with religious beliefs rather than content knowledge. One teacher arrived late at the workshop, increasing the SAASTE sample to 39 and, hence the sample size increased to 79. The results obtained from the 14 evolution content misconceptions have been summarised in the Table 11 below. The prevalence of the misconceptions has been classified into five categories.

None – where there were no misconceptions at all.
Rare – where fewer than 16% of the 14 statements were erroneous (only one or two).
Occasional – from 17 to 33% were erroneous (i.e. there were three or four misconceptions).
Frequent - from 34 to 65% of answers were incorrect (6 to 9 misconceptions occurred).
Extensive – more than 66% of the answers were incorrect (10 to 14 misconceptions identified).

Table 11: The extent of the teachers' misconceptions (n=79)

Extent of misconceptions			Frequency of teachers per category		
Category description	No. of statements incorrect (out of 14)	% of statements incorrect	SAASTE (n=39)	NAPTOSA (n=40)	TOTAL (n=79)
None	0	0	0	0	0
Rare	1-2	Up to 16%	0	1	1 (1%)
Occasional	3-5	17-33%	5	12	17 (22%)
Frequent	6-9	34-65%	17	19	36 (46%)
Extensive	10-14	>66%	17	8	25 (32%)

The data in the table gives the general picture of the number of teachers who hold evolution misconceptions. Teachers should have started teaching evolution no later than mid-July, the first week of the third term. Thus the SAASTE teachers were about to start teaching it at the time of their workshop, whilst the NAPTOSA teachers should already have started teaching it at the time of data collection. It is very worrying to note that only a single teacher had fewer than three misconceptions (rare). Just below half of teachers (46%) had 'frequent" misconceptions and just under a third (32%) had "extensive" misconceptions. This is disturbing because when teachers plan for teaching any topic, they must be aware of the likely misconceptions that learners may bring to class, so that they can come up with strategies to challenge these misconceptions. However, if they themselves are not even aware of their own misconceptions the consequences are that incorrect scientific knowledge will be taught in class and learners' misconceptions will be left unchallenged.

The graph on the next page gives a picture of the prevalence of the misconceptions held by teachers in the two groups. I calculated the averages for the data collected from both the SAASTE and the NAPTOSA samples for each misconception. I then classified the misconceptions into five categories to show prevalence of the total number of misconceptions among the teachers. Although the same terms are used as to describe the extent of the individual teachers' misconceptions (see Table 11 on page 54), these terms are used differently here – to look at the extent of a whole groups' misconceptions about particular aspects of evolution. The categories used to classify the data are:

- **Rare** – refers to misconceptions held by fewer than 20% of the teachers. Two misconceptions belong to this category. First is the error that all individuals in a species evolve at the same time (9%). Rutledge and Warden (2000) reported on the same error at similar levels in their USA study with teachers. Although the majority of the teachers in this study seem not to have the misconception, it is possible that the reasoning of those who do is based on the biblical account in the book of Genesis that all organisms, including humans, were created in six days. Teachers need to be aware of the basis or the sources of their learners' conceptions. The second misconception in the *rare* category, held by 14% of the teachers, is that "life first appeared on Earth less than 10,000 years ago". This, too, could be affected by creationist beliefs. In 1650 Ussher used calculations based on the age of people mentioned in the bible to claim that the Earth was created 4004 BC (Moore *et al.*, 2010). Today many people still believe that the

Earth is only about 6,000 years old. The fossil record shows an abundance of evidence of organisms that inhabited the Earth from 540 million years ago (National Academy of Sciences, 2008).

- **Occasional** – refers to the misconceptions held by 20 – 39% of the teachers. One statement fits into this category – that "evolution takes place for humans to evolve", which was held by 37% of the teachers. This error may be due to lack scientific knowledge about evolution. Evolution has no intentions (Freeman & Herron, 2004) and it is not gearing towards some end point or development of humans.

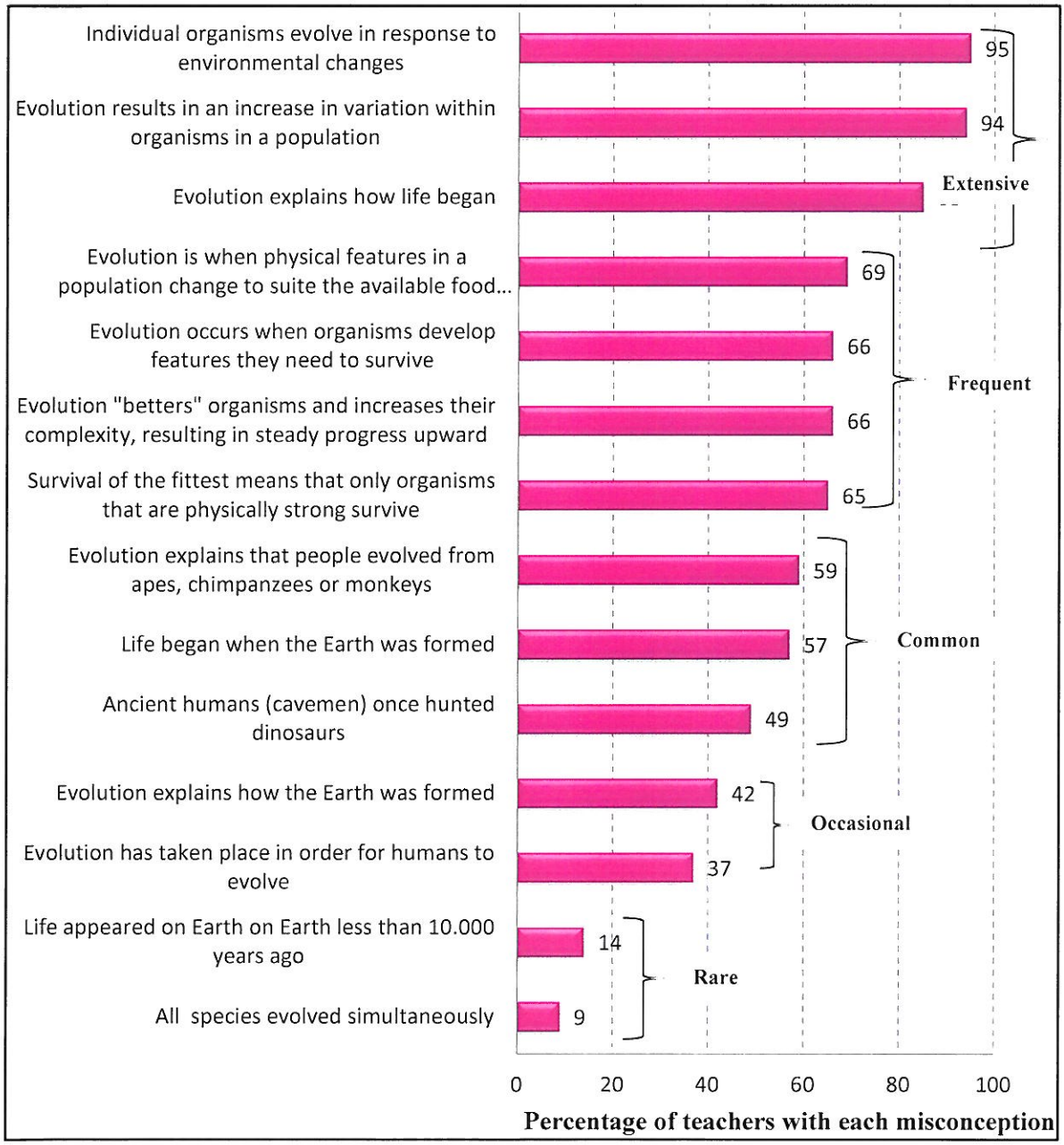

Figure 7: The percentage of teachers with various misconceptions

- **Common** – refers to errors held by 40 - 59% of the teachers. Data on the graph indicates that four statements fit into this category. The first misconception, held by 42% of the teachers, was that "evolution explains how the Earth was formed". This statement is incorrect as the central focus of evolution is to explain how life has changed after the origin of the Earth, because the origin of the universe produced conditions necessary for evolution (National Academy of Science, 2008). The second misconception, held by 49% of the teachers, is that "ancient humans (cavemen) once hunted dinosaurs". This error may be a consequence of lack of knowledge of the history of life and lack of understanding of the geological time-scale. Prinou *et al.* (2008) reported this error held by 35% of 182 people in their study in Greece, and Moore *et al.* (2006) in Minnesota, although neither study involved teachers. The statement is incorrect because the earliest human ancestors only appeared on Earth about 5.3 million years ago whilst dinosaurs became extinct about 65 million years ago (Reece *et al.*, 2011). Thirdly, 57% of the teachers held the misconception that "life began when the Earth was formed". This statement is incorrect as the Earth is estimated to be between 4.5 and 4.6 billion years old and the earliest forms of life appeared only 540 million years after the Earth was formed (National Academy of Sciences, 2008). This misconception may be because of the literal interpretation of the book of Genesis in the Bible by the Young Earth Christians, who believe that the Earth and all life forms were created in one week. The fourth misconception in this category is that "evolution explains that people evolved from apes, chimpanzees or monkeys". This error was held 59% of the teachers. This misconception has been reported in many studies (Boujaoude, Wiles, Asghar & Alters, 2011; Robbins & Roy, 2007; Clores & Limjap, 2006; Dagher & Boujaoude, 1997; Bizzo, 1994). This misconception may be a consequence of an incorrect understanding of the mechanism of evolution. In fact, there is overwhelming evidence that humans share a common ancestor with the gorillas and the chimpanzees, but evolved separately from that ancestor (Reece *et al.*, 2011). This misconception is also encouraged by pictures in the media of the human ancestor showing the ape-like ancestor. The evolutionary history of primates, especially the genus *Homo,* can clearly be seen using a phylogenetic tree or human evolution timeline to show where the split occurs, and that chimpanzees and humans evolved separately.

- **Frequent** - refers to misconceptions held by 60 - 79% of the teachers. Four statements fit into this category, all of which are associated with a misunderstanding of the mechanisms of evolution by natural selection. The first misconception, held by 66% of the teachers, is that "evolution 'betters' organisms and increases their complexity, resulting in a steady progress upward". Moore *et al.* (2005) have reported this error with 25% of the 107 teachers in their study in Minnesota. Rutledge and Warden (2000) reported that 14.5% of the teachers in their study in Indiana indicated that evolution is *"change of simple to complex organisms"*, a statement that implies that evolution results in organisms continually becoming better. The mechanism of natural selection results in the evolution of improved abilities of populations to survive and reproduce in their particular niche, and does not mean that evolution is progressive and leading to some predetermined advanced type of organism (The University of California Museum of Palaeontology, Berkeley, 2006). Evolution does not lead to forms that are more advanced but makes organisms better *"only in the sense of increasing their adaptation to the environment"* (Freeman & Herron, 2004:91). Once suited to their environment they do not evolve further, into the so-called "higher organisms".

The following misconceptions in the "frequent" category may be a consequence of Lamarckian ideas. First is the misconception held by 65% of the teachers that "survival of the fittest means that only organisms that are physically strong survive". The second one is the misconception held by 66% of the teachers that "evolution occurs when organisms develop features they need to survive". The third one, held by 69% of the teachers, is that "evolution is when physical features in a population change to suite the available food source". Natural selection is a mechanism proposed by Darwin that explains how evolution occurs. Teachers must know that individual organisms do not evolve, but it is populations that evolve (Gregory, 2009). Natural selection acts on individuals but its results occur in populations (Freeman & Herron, 2004). Natural selection does not have intentions. Existing genetic variations within populations are an essential condition for evolution (Bishop & Anderson, 1990). The environment does not make organisms change nor do organisms change due to environmental changes. The word "adaptation" in everyday language implies that individuals can change their behaviour at will (as could be the case with thinking organisms such as humans, who can change their behaviours to improve their living conditions). However, the scientific meaning of "adaptation" refers to characteristics that enable organisms to survive and reproduce more successfully (Bishop & Anderson, 1990; Ridley, 2004). Natural selection does not give organisms features they need to survive, but favours those organisms that already have the characteristics that enable them to survive (Gregory, 2009). A second risk term often encountered when teaching evolution is "fitness". In everyday language, "fitness" means healthy or strong and it has a different meaning to a scientific fitness, which refers to genetic traits that increase an organism's ability to reproduce successfully (Bishop & Anderson, 1990; Gregory, 2009).

- **Extensive** - refers to misconceptions held by more than 80% of the teachers. Three statements fitted into this category. The first misconception in this "extensive" category, held 85% of the teachers, is that "evolution explains how life began". This misconception is held by many creationists and the public in general (Pigliucci, 2002) and is partially the reason why there is resistance to the acceptance of the evolutionary theory by the public (Rice, Warner, Kelly, Clough & Colbert, 2010). The central focus of evolution is not on the origin of life. Evolution provides an explanation of how life diversified after its origin (The University of California Museum of Palaeontology, Berkeley, 2006). Rice *et al.* (2010) indicate that the theory of evolution does not provide nor does it require an explanation for the origin of life. The second extensive misconception, held by 94% of the teachers, is that "evolution results in an increase in variation within organisms in a population". Evolution does not result in individual variation. In fact, genetic variation provides raw material for evolutionary change (Reece, 2011). Phenotypic variation is a reflection of genetic variation, which is a product of mutation and sexual reproduction and may result in the production of new alleles and new genes (Reece, 2011). Evolution (by natural selection) depletes genetic variation within populations (Gregory, 2009) but may result in new taxonomic groups. The third, and the most common misconception, held by 95% of the teachers, is that "individual organisms evolve in response to environmental changes". As already stated above, this misconception is a consequence of Lamarckian ideas. Firstly, individual organisms do not evolve – populations do (Gregory, 2009). Secondly, the environment does not make organisms change. Their basic genetic makeup is fixed for the duration of their lives, apart from localised mutations (such as cancer).

The graph in Figure 8 on the next page shows the frequencies of the misconceptions identified from the two groups of teachers (NAPTOSA and SAASTE) separately. They are ranked according to the frequencies of the responses of the SAASTE teachers from highest to lowest. The darker shaded bars indicate the statements where the differences between the frequencies of the two group were above 10%, while the lighter shaded bars indicate the statements where the differences between the frequencies were less than 10%. I needed to make the comparison between the two groups to see if there would be differences or similarities in the frequencies of the misconceptions held by teachers in the two groups that may help me to generalise the results.

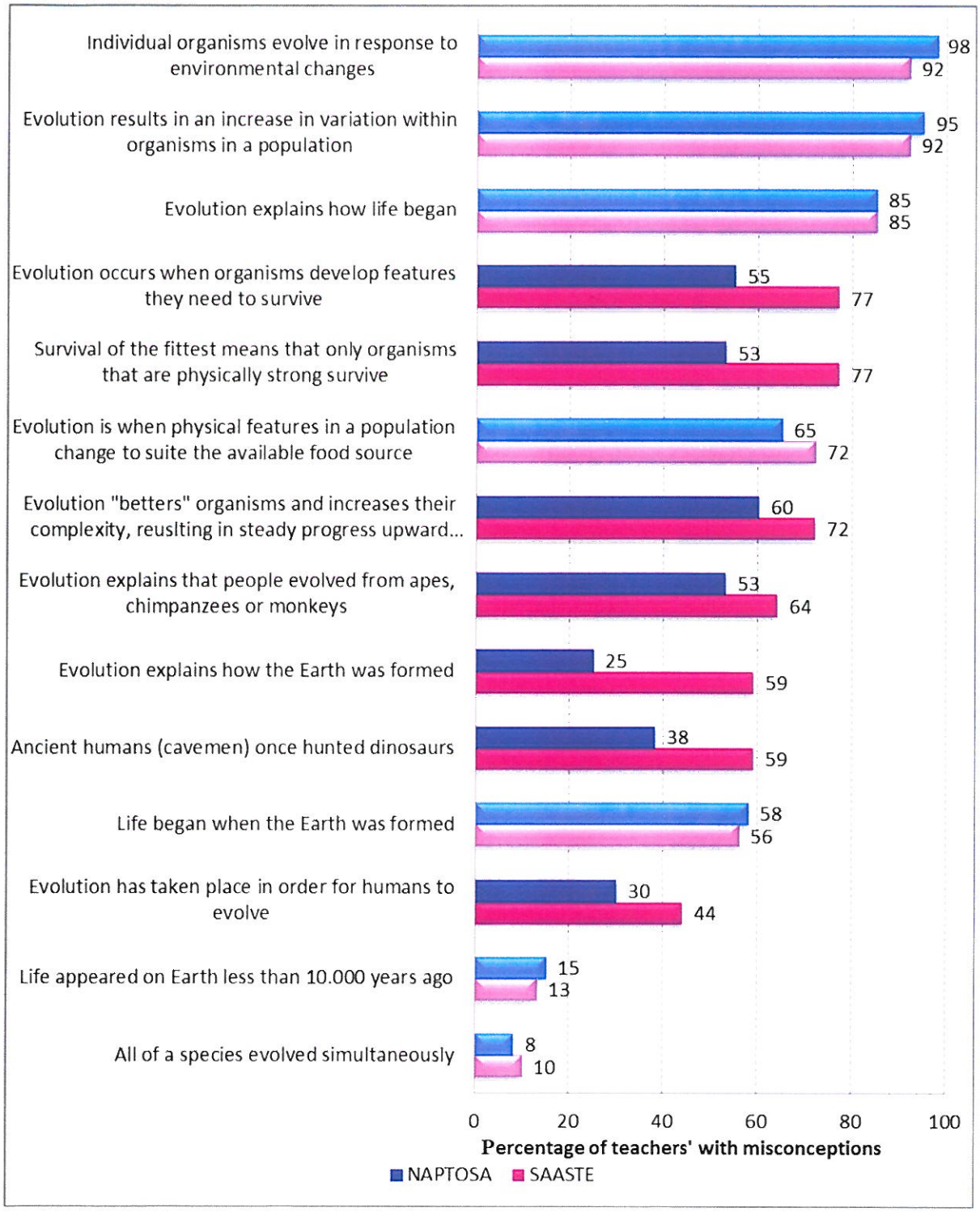

Figure 8: The frequency of misconceptions in the NAPTOSA and SAASTE groups of teachers

Data were collected from the two samples at different times. The first set of data was collected from the SAASTE group in a workshop held on the 2nd of July 2008, two weeks before the schools reopened for the third term. The second set of data was collected from the NAPTOSA group on the 2nd August 2008, 2½ weeks into the third term.

There was a difference of more than 10% between the frequencies of the two groups in seven statements. For example, 25% of NAPTOSA teachers and 59% of SAASTE teachers held the misconception that "evolution explains how the Earth was formed", a difference of 34%. A second misconception, in which difference between the frequencies of the two groups was 25%, was that "ancient humans (cavemen) once hunted dinosaurs" held by 38% of NAPTOSA teachers and 59% of SAASTE teachers. The third misconception, with a difference of 24% between the frequencies of the two groups, was "survival of the fittest means that only organisms that are physically strong survive", held by 53% of NAPTOSA teachers and 77% of the SAASTE teachers. A trend can be seen in the differences of the frequencies between the two groups. In all the statements where there is a difference of more than 10%, the SAASTE teachers show a greater frequency of misconceptions than the NAPTOSA teachers. The differences in the frequencies of the seven misconceptions held by the two groups could be as a result of timing of the workshops. The NAPTOSA teachers' data was collected at a time when they had already started teaching evolution, and should have been exposed to evolution content. Some of them might have been able to correct the potential misconceptions because they had read more as they prepared their lessons. It is worrying to see such a high number of teachers holding so many erroneous ideas about evolution, especially at a time when they should be teaching the topic or preparing to teach it. The SAASTE teachers might have intended to do their preparation for the start of the third term, during the last two weeks of the school holidays.

4.3 KNOWLEDGE OF MISCONCEPTIONS LEARNERS ARE LIKELY TO BRING TO CLASS

The second sub-question in this study was based on the second of five sub-categories of PCK in the model I was using, and targeted teachers' knowledge of learners' prior ideas, including misconceptions about evolution that learners may bring to class.

Research sub-question 2:	What common misconceptions associated with evolution did the teachers know about?

Students' knowledge about evolution includes many incorrect ideas commonly found in students in all grades (Smith, 2010). Teachers need to consider these incorrect ideas when planning to teach evolution, so that they can address them. Teachers were given activity-based questionnaire 4 (see Appendix C7) to determine their awareness of erroneous prior ideas learners bring to class. This questionnaire was administered near the start of the workshop, before any misconceptions were discussed. The questionnaire asked, *"Do you know any misconceptions that learners may have about evolution?"* and there was an option of answering *"yes" or "no"*, with a follow-up question *"if you answered "yes", list them (misconceptions) below"*. Only the NAPTOSA teachers (38) were given this questionnaire, as their full-morning workshop allowed time for this, whist the shorter 90-minute workshop for the SAASTE teachers did not. Of the 38 teachers who responded to this questionnaire, seven indicated (by choosing the options "no") that they had no knowledge of the misconceptions about evolution that learners may bring to class. Thirty-one chose the "yes" option and listed the misconceptions. Table 12 on the next page shows the misconceptions that the teachers thought learners would bring to class.

Table 12: Misconceptions that teachers say learners have about evolution (n=31)

Learners' likely misconceptions	Frequency
Evolution explains that humans are descendants of apes or monkeys	12
Evolution contradicts the bible	6
Evolution is against God or creation	6
Only black people evolved from monkeys	4
All living things were created by God in 6 days	2
Humans were created by God exactly the way they are today	1
Evolution has stopped	1
Only humans evolve	1
Humans are not animals	1
Evolution is just a theory	1
Fossils are only for movie purposes (Jurassic Park)	1

The teachers identified eleven erroneous ideas that learners may have about evolution. The most prevalent erroneous idea they were aware of, identified by twelve teachers, is that humans come from monkeys. This erroneous idea is classified with the misconceptions that are associated with the mechanism of evolution (see Chapter 2, pp. 24-26). There were two second- most-common erroneous ideas (see Table 12), each identified by six teachers, are both associated with religious beliefs.

Of particular interest are the two misconceptions that "only black people evolved from monkeys" and that "fossils are only for movie purpose (Jurassic Park)". The erroneous idea that black people evolved from monkeys (mentioned by four teachers) could be a consequence of what is usually depicted in the pictures showing human evolution, which shows the ape-like ancestor evolving into a black human ancestor, and eventually showing modern man as a white person. Teachers need to teach learners the correct science that all humans belong to the same species and that individuals in a species have variations. Based on fossil and genetic evidence, scientists agree that central Africa is the cradle of humankind. Human skin colour has been determined by natural selection. Because of the powerful African sun (high levels of ultra-violet rays), ancestors of modern man had darker skin colour, an adaptation resulting which was an advantage in terms of limiting skin cancer. The other known effect of the sunrays is that they stimulate the skin to produce vitamin D, which is important for bone growth and prevents rickets (Kirchweger, 2001; Muehlenbein, 2010). About 10,000- 50,000 years ago, early humans migrated further north to Europe. In Europe, the sun was less powerful (lower levels of ultra-violet rays) than in Africa and this resulted in a decrease in the production of melanin and the skin became lighter. Reduction in the ability of dark-skinned individuals to absorb the reduced amounts of sunlight resulted in the decrease in the production of vitamin D, and this resulted in the decrease in the life expectancy. Those individuals with variations for lighter skin still produced vitamin D despite the less powerful sun were selected for and thus the frequency for light coloured skin increased (Kirchweger, 2001).

4.4 KNOWLEDGE OF LIKELY TEACHING AND LEARNING DIFFICULTIES

Besterman and Baggott la Velle (2007) indicate that evolution is one of the most challenging topics to teach. Shulman (1986) says that pedagogical content knowledge includes understanding of what makes a particular topic difficult or easy to learn. Concerning the learning of evolution, Shulman says

that is very important for the teachers to understand what is it that makes evolutionary theory difficult to **learn** (Berry *et al.*, 2008). I was also interested in knowing the **teaching** difficulties that they anticipated when teaching evolution, particularly as studies show that evolution is not an easy topic to teach.

The third sub-question therefore targeted the teachers' knowledge of the difficulties associated with both the **learning** and **teaching** of evolution.

Research sub-question 3:	What did the teachers know about likely learning and teaching difficulties they could anticipate when teaching evolution?

The aim of this question was to find out if teachers have any knowledge about the teaching difficulties they may encounter when teaching evolution, as well as the learning difficulties they may anticipate from the learners. The teachers were given activity-based questionnaire 3 (see appendix C6) asking them the following two questions: *"what difficulties have YOU experienced/ do you think you might experience teaching evolution?"* and *"what difficulties do you think LEARNERS might have, when learning about evolution?"* Only the NAPTOSA teachers were given this questionnaire.

4.4.1 Knowledge of difficulties teachers might encounter

Forty-two teachers responded to this questionnaire. The teachers' responses were clustered into eight categories, as shown Table 13.

Table 13: Summary of teaching difficulties teachers thought they might encounter when teaching evolution (n=42)

Teaching difficulties relating to...			**Frequency**
Teachers' inadequate knowledge			40 (95%)
Controversial nature of the topic			28 (67%)
Problems with resources, or lack thereof			14 (33%)
Time-related problems			13 (31%)
Attitude-related problems			10 (24%)
The topic itself	terminology	4	10 (24%)
	too much content	2	
	new and unfamiliar	3	
	too difficult	1	
Perceived difficulties			6 (14%)
Learners' existing misconceptions			3 (7%)

- **Teachers' inadequate knowledge**: Of the 42 teachers who responded to this questionnaire, 40 (95%) indicated that their inadequate knowledge of evolution was a potential source of difficulty they would encounter when teaching the topic. To be able to effectively transform knowledge into content that learners can access, teachers must first master the subject matter they are required to teach (Shulman, 1986). Stears (2006) indicated that South African teachers

at that time were ill prepared to teach evolution as many were not formally trained in the principles of evolution and therefore lacked adequate content knowledge. The teachers themselves acknowledged this, making the following sorts of comments:

"Insufficient knowledge about evolution since it was never part of our training" [#32.N];

"Knowledge – new. Unfamiliar knowledge, have to study it before can teach" [#34.N];

"Foreign module to learners and teachers" [#16.N];

"Wonder whether my knowledge will be enough to be able to answer all questions" [#6.N]

"Thorough knowledge of the content" [#9.N];

"Teachers' lack of confidence to give the correct responses to some questions raised by learners" [#32.N]

Data revealed in this study seem to be consistent with Stears' claims. Moolla *et al.* (2004) say that inadequate content knowledge is a factor in determining the level of confidence of teachers to teach a particular topic. If the teachers lack confidence, the consequence is that they will resort to transmission of facts and learners will respond by memorising disjointed facts (Geddis *et al.*, 1992). Rutledge and Warden (2002:25) say that teachers who do not have adequate knowledge about evolutionary theory are not capable of *"making professionally responsible instructional"* decisions on evolution teaching.

- **Controversial nature of the topic:** 67% of the teachers indicated the controversial nature of the evolution to be a difficulty they might encounter. The controversial nature of evolution has been reported in many studies in the USA as one of the leading problems in the teaching of evolution (Osif, 1997; Rutledge & Warden, 2000; Antolin & Herbers, 2001; Gerking, 2003; Wuerth, 2004; Moore, 2008). The comments made by teachers related to the evolution-religion controversy, for example:

  "Pupils' questions, especially trying to explain Adam and Eve vs. evolution of man" [#26.N];

  "Conflict with my Christian beliefs and viewpoints" [#35.N];

  "My own biases. Cannot take religion out of the equation" [#42.N];

  "It conflicts with my beliefs, it will be rather difficult for me to inculcate it in others" [#10.N];

  "I do not believe in evolution. It is against my belief so I do not like it" [#39.N].

  When teaching evolution some teachers are challenged by their own personal beliefs, which conflict with evolution. Trani (2004) indicates that teachers with strong religious conviction show little acceptance of evolution theory, and Rutledge and Warden (2002) found that there was a relationship between teachers' acceptance of evolution and their emphasis on evolution when they teach. This controversy could be attributed to the misconception that evolution contradicts religion. This gives the impression that evolution and religion are incompatible and people have to choose to believe one of the two. Christians, who believe the literal interpretation of the biblical accounts of creation, as outlined in the book of Genesis, tend to see conflict between evolution and religion. Evolution and religion are very different realms. They are based on different aspects of human experience. In science, explanations are based on

empirical evidence drawn from the natural world. If observations and experimentation are in conflict with an explanation this may lead to modification or even abandonment of that explanation. Religion, on the other hand, is not based on empirical evidence, but on faith and beliefs that are beyond the natural world. The idea that people with religious convictions cannot believe in evolution is incorrect. Many religions and individuals accept the theory of evolution by natural selection as one of the most successful theories in the biological sciences (Freeman & Herron, 2004). Many religious denominations have issued statements that evolution and their faiths are compatible (National Academy of Sciences, 2008).

It is interesting to note that 33% of the teachers did not see the evolution-creation controversy as something which might cause them difficulties when teaching the topic of evolution.

- **Problems with resources:** 33% of the teachers cited lack of resources to teach evolution as a difficulty they anticipated. Some of the comments include:

  "Not having enough resources to teach evolution" [#8.N];

  "Inadequacy of teaching resources" [#37.N];

  "Limited or no resources to support the topic" [#27.N].

  In South Africa, many teachers rely mostly on textbooks for information, especially in the cases where training was inadequate. The approved new *Life Sciences* textbooks were organised differently and in some cases, even the depth of content was different. One teacher commented

  "Different text, which one is reliable?" [#16.N]

- **Time-related problems:** Thirteen teachers (31%) indicated that there was not enough time to cover the entire evolution content required by the National Curriculum Statement. This may be a consequence of poor planning on the side of the teachers, or teachers may have felt overwhelmed by the amount of evolution content to be covered (see Chapter 1,Table 1, pp 2-3) especially because the content was new to most of them. Some comments made were:

  "Time required for background reading, lesson planning" [#26.N];

  "Not enough time to teach the content and do all the activities" [#25.N];

  "Too little time to do justice to the problem" [#21.N];

  "Content to cover, time available" [#43.N];

  "Inadequate teaching and learning time to cover the syllabus" [#9.N].

  There is a possible justification for teachers' difficulties with the amount of content and the small amount of time allocated to teaching it. The Grade 12 work schedule suggested in the Learning Programme Guideline for *Life Sciences* (Department of Education, 2008b) suggests a total of seven weeks in which teachers are to teach evolution. The total number of teaching weeks for the Grade 12 class in the third term was six weeks, as the learners had to start writing their preliminary examination from the last week of August. Taking all factors (new content, inadequate training, and the controversial nature of the topic) into account, the teachers' worries might well have been justified. Ngxola (2012) indicates that for an innovation to be successful,

carefully planned guidelines are essential as they give practical guidance to teachers and help them plan for sequenced learning, teaching and assessment.

- **Difficulty with the topic itself:** Evolution terminology, too much content, the content being new and unfamiliar, and the difficulty associated with evolution, were difficulties 10 teachers cited that they might encounter. Besterman & Baggot la Velle (2007) assert that evolution is one of the most challenging topics to present in class, especially because the "*nature of the subject does not lend itself to practical work*", which may lead to learners being bored. Teachers made comments such as

  "*Foreign module to learners/educators*" [#16.N];

  "*Terminology and spelling/pronunciation*" [#34.N];

- **Attitude-related problems:** About a quarter of the teachers (24%) mentioned attitude (negative) towards the topic as an anticipated difficulty. The teachers were anticipating negative attitudes from parents and the community members who might refuse to allow their children to be taught evolution. Some of the comments made were

  "*Parents who are religious won't want their kids to think of evolution instead of creation*" [#10.N];

  "*Opposition from other people. Think you are challenging a (sic) God*" [#38.N].

  Some negative attitudes could also stem from the teachers' themselves as they could experience conflicting emotions between evolution and their religious beliefs. One teacher commented that "*I do not believe in evolution. It is against my religious beliefs so I do not like it*" [#39.N]. The attitude-related problems are mostly linked to religious beliefs as reported by Aguillard (1999) and Rutledge and Warden (2000). Rutledge and Warden (2000) point out that teachers' negative attitudes about evolution teaching can badly affect the instruction on evolution and this may negatively affect learners' performance.

4.4.2 Knowledge of typical learning difficulties

Teachers were asked the question "*what difficulties do you think learners might have, when learning about evolution?*" thirty-nine teachers responded to this questionnaire. The responses were clustered into 10 categories, as shown in Table 14 on the next page.

Table 14: Summary of learning difficulties teachers anticipated for learners when learning about evolution (n=39)

Learners' difficulties teachers anticipate	Frequency
Dealing with the controversial nature of the topic	28 (72%)
Problems with the topic itself	18 (46%)
Attitude-related problems	7(18%)
Inadequate prior knowledge	6 (15%)
Lack of insight	5 (13%)
Time-related problems	4 (10%)
Lack of resources	3 (8%)
Language barrier	2 (5%)
Lack of personal experience/ observation	2 (5%)
Incoherent/ irrelevant	2 (5%)

Difficulties that teachers anticipated from learners were multi-faceted. Almost three-quarters of the teachers (72%) anticipated learners would have difficulties dealing with the controversy around evolution. One of the factors associated with the controversial nature of the topic has to do with learners' attitudes and emotions towards religion and evolution.

> *"Lack of interest from the learners' side on this topic"* [#36.N].
>
> *"Learners' resistance to accept evolutionary change due to religious beliefs"* [#37.N];

Studies by Asghar *et al.*, (2007) and Moore (2007) show that one of the factors that have a negative impact on the teaching of evolution is the learners who are non-receptive to evolution instruction due to their religious convictions. People, who believe the literal interpretation of the biblical accounts of creation, as outlined in the book of Genesis, tend to see conflict between evolution and religion. The Christian clergy from different churches come in support of the theory of evolution as a foundational scientific truth and state *"to reject the truth ... is to deliberately embrace scientific ignorance"* (The Clergy Letter Project, 2006).

Almost half of the teachers (46%) anticipated, or had already experienced, that the learning difficulties learners may experience would be related to the topic itself.

> *"Learners do not understand the real aspect of it"* [#18.N];
>
> *"Too much information for learners to grasp quickly"* [#21.N];
>
> *"List of examples – not enough for learners to understand different parts of evolution"* [#28.N];
>
> *"Lack of enthusiasm due to lack of knowledge and religious beliefs"* [#35.N].

Teachers need to be aware of the learning difficulties associated with the teaching and learning of evolution in order to make pedagogically and instructionally sound decisions for effective teaching of this topic.

4.5 KNOWLEDGE OF APPROPRIATE TEACHING STRATEGIES FOR EVOLUTION

Research sub-question 5: What teaching strategies did the teachers know about on how to increase learners' understanding of evolution?

Teachers were not given a questionnaire to respond to. I took into consideration that these teachers were teaching evolution for the first time, and that at the time of data collection they probably had not developed any strategies as they were only experiencing learning challenges for the first time. However, data to answer this questionnaire was extrapolated from the responses given by teachers when they answered the question about the teaching difficulties they were anticipating when teaching evolution. Data revealed that:

- Thirteen teachers (31% of the teachers) said that they unsure about how to teach evolution.
- Twenty-seven (64%) said that they did not know how to deal with the controversy.
- Five teachers (12%) said that they were unsure about what activities to include when teaching evolution.

Thirteen teachers (of the 42) indicated that they were not sure how to teach evolution. This may be an indication that they did not know how to approach the topic or they were not aware of the teaching strategies that could be used when teaching evolution. When they were responding to the questionnaire of the teaching difficulties they were anticipating when teaching evolution, teachers made comments such as:

> *"Make learners understand concepts-eras"* [#24.N] – this may be an implication that that the teachers does not know appropriate strategies to teach the concept of geological time scale (eras and periods).
>
> *"Ways of putting it across to learners"* [#5.N] - an indication that the teacher may not know how to approach evolution.
>
> *"Trying to prevent a lesson turning into a very heated lesson, because of viewpoints"* [#40.N] – an indication that the teacher do not have strategies to prevent conflict or maybe how to deal with conflict should it arise.

The teaching and learning of evolution is conceptually challenging and teachers need to explore new teaching approaches and strategies to increase understanding (Besterman & Baggott la Velle, 2007; Nadelson, 2009). Many education researchers agree that traditional teaching of evolution is not very effective since many people still do not have the correct understanding about evolution even after having being taught this concept (e.g. Besterman & Baggott la Velle, 2007; Lombrozo *et al.* 2008). Several teaching strategies are suggested in the literature to increase students' understanding of evolution. One of the strategies suggested by Nelson (2008) is the use of interactive engagement of students in heads-on and hands-on activities, which will culminate in immediate feedback through class discussion with peers and/or the teacher. This strategy by Nelson includes extensive structuring of learning activities by the teacher, followed by strongly interactive student-student execution of the

task, then effective debriefing that provides immediate feedback and finally instructional modification by the teacher. They also suggest the development of scientifically correct criteria about evolution concepts for comparing with the alternative ideas learners may have, and include the confirmation by "fair test". Learners then use these criteria to judge their own alternative ideas. Based on the judgements the learners can realise if their ideas are scientifically correct or not. However, if teachers themselves have misconceptions, even if they use the approved methods, this may not result in successful teaching and learning of evolution.

Twenty-seven teachers (64%) indicated that they did not know how to deal with the controversy surrounding the teaching of evolution and religion. The literature shows that the controversy behind teaching evolution largely stems from religious fundamentalists, some of whom ask for equal time to teach evolution and creation in the classroom (Clough, 1994; Hemenway, 1999; Meadows, Doster & Jackson, 2000; Rutledge & Warden, 2000). Examples of teachers' comments when responding to the questionnaire that asked them if they knew of strategies of how to make evolution understandable to learners were:

> *"Teaching it without offending the religious beliefs and personal opinions of individual learners."* [#7.N];
>
> *"Conflict of interest religiously. Every learner believes their religion supports discovery"* [#27.N];
>
> *"Parents who are religious won't want their kids to think of evolution instead of creation"* [#10.N].

Studies show that evolution is one of the most difficult topics to teach, thus requiring teachers to develop "pharmacopeia" of strategies and approaches to make it conceptually accessible to learners. Before teachers can come up with strategies to teach evolution effectively, they first have to know what it is that makes the learning of evolution difficult. Clough (1994) suggests a number of strategies to promote a functional understanding of evolution and to avoid controversy. The first is separating evolution from debates concerning the origin of life. The second is teaching about the correct scientific meaning of the word "theory "as used when referring to "the theory of evolution". A third is teaching the nature of science, to explain how science works in order to be able to distinguish between science and non-science. The fourth strategy includes stressing the functional understanding of evolution by showing learners how evolution theory works (its predictability, explanatory power and research framework). The fifth strategy involves the fact that knowledge is not democratic for selecting content in biology

4.6 KNOWLEDGE ABOUT CURRICULAR MATTERS

The fifth questionnaire targeted the teachers' curricular knowledge evolution. Thirty-six NAPTOSA teachers responded to this questionnaire which targeted their *"knowledge of what is taught about evolution, and when"* (See Appendix C5).

Research sub-question 4: What was the teachers' curricular knowledge for teaching evolution?

Shulman (1986) explains that curricular knowledge involves the teachers' knowledge of the depth and breadth of what to teach, how a particular topic links to topics taught in previous and future grades and how it links with topics in other subjects. He believed that curricular knowledge also included knowing about the different programmes that are available to teach a particular topic, and the variety of available instructional materials.

Three questions were used to identify teachers' curricular knowledge about evolution. The first question asked teachers *"in which other learning areas / subjects and grades is evolution (or aspects of evolution) taught"*? They were asked to list the learning area/ subject, the grade and the topics that contained evolution or aspects of evolution. Table 15 shows the summary of the teachers' responses to this question.

Table 15: Summary of teachers' knowledge about other subjects/learning areas in which aspects of evolution are taught (n=36)

Subject with evolution or aspects of evolution	Frequency
Life sciences (Grades 10 & 11)	10 (28%)
Natural sciences (Grades 7 – 9)	11 (32%)
Social sciences (Grade 7)	13 (35%)
No response	5 (14%)

It should be noted that the frequencies in the table do not tally with the sample size because some teachers mentioned more than one subject, others mentioned one or two of the three subject

Of the thirty-six teachers who responded to this questionnaire, some teachers indicated knowledge of the aspects of evolution being taught in the three different subjects (*Life Sciences, Natural Sciences and Social Sciences*) in the different grades mentioned in the table above, others mention one or two subjects and grades. Just under a third of the teachers (28%) indicated that they knew of some aspect of evolution that were taught in Grade 10 & 11 *Life Sciences* (classification, biodiversity, adaptations, fossils). However, no evolution per se was taught in the Gr 10 or 11 NCS in 2008, this was only changed after a full cycle of the original NCS had been completed. Just above a third of the teachers (32%) were aware of evolution or aspects of evolution taught in *Natural Sciences* Grades 7-9 (natural selection, adaptation of plants and animals, Darwin & Lamarck). Thirteen teachers (35%) indicated that they knew that aspect of evolution and evolution were taught in lower grades of *Social sciences* (evolution of mankind, age of rocks, Darwin, hominids, cradle of humankind). Shulman (1986) indicates that one of the aspects of curricular knowledge is the vertical curriculum knowledge, which is the teachers' knowledge to relate the content of a particular lesson to topics being taught in other grades. Furthermore, one of the nine requirements of the new South African curriculum is that learning should be integrated across learning areas. Thus, teachers teaching evolution need to be aware of aspects of evolution being taught in other subjects and incorporate them into lessons by making links so that evolution is not taught in isolation

The second question asked the teachers *"how confident are you about the amount of detail you should include when teaching about evolution at different grade levels (including Grade 12)?"* (See Appendix C5). Shulman (1986 & 1987) indicates that one other important aspect of curricular knowledge is establishing the depth and breadth of the content to be taught at a particular grade level. Teachers cannot establish this on their own and need to be guided by the policy documents such as the

National Curriculum Statement, the Learning Programme Guideline and the Examination Guidelines provided by the National Department of Education.

Table 16: Teachers' level of confidence about the amount of detail they should include when teaching evolution (n=36)

Confidence level	Frequency
Very sure	1 (3%)
Fairly sure	16 (44%)
Not sure	18 (50%)
No response	2 (6%)

Only one teacher felt very confident about the amount of evolution detail to teach. Judging by the responses of the teachers (see Table 16) more than half of the teachers (18 + 2) seem not to be fully aware of this aspect and a further 43% were only "fairly sure". Teachers cannot rely on textbooks for content depth and breadth as the authors themselves were just interpreting the National Curriculum Statements; as such, the amount of detail in the available textbooks differs a great deal. Sanders (2008) suggests that teachers use exemplar question papers, the examination guidelines (National Department of Education, 2008) and the policy documents to establish the breadth and depth of what they need to teach in evolution. However, teachers could also use the grade examination guidelines which specified evolution content which was to be taught (see Table 1, on page 2-3).

The third question (see Appendix C5), asked the teachers *"how well do you know about specific resources which are available?"* The purpose of this activity was to find out the teachers' knowledge of appropriate instructional materials there are for evolution. A list of various resources was given to teachers and they were to indicate the extent of their knowledge with each resource (see Appendix C5).

Table 17: Summary of teachers' knowledge about the available instructional material for teaching evolution (n=36)

How well teachers knew resources	Resources			
	Books	Videos/ DVDs	Models	Interactive internet activities
Very well	8 (22%)	3 (8%)	1 (3%)	3 (8%)
Well	18 (50%)	8 (22%)	10 (28%)	1 (3%)
Don't know of many	10 (28%)	24 (67%)	24 (67%)	31 (86%)
No response	1 (3%)	2 (6%)	2 (6%)	2 (6%)

Shulman (1986:10) indicates, *"the curriculum and its associated materials are the materia medica ... from which the teacher draws those tools of teaching"*. They need to make content accessible to learners and are therefore expected to have knowledge of the whole range of such materials when teaching evolution. About a quarter of teachers (28%) indicated that they did not know of many books that are available on evolution. Textbooks and guidelines are often silent about the misconceptions, and effective teaching strategies about evolution, and teachers therefore need to consult different sources of information such as research journals, scientific magazines, DVDs, models and interactive internet activities. Many research journals address the misconceptions in evolution, and some of the DVDs and the internet interactive activities can help learners to make sense of how evolution occurs and may dispel misconceptions that learners may be harbouring. The majority of teachers (67%)

mentioned that they did not know of videos and models that could be used to demonstrate different aspects of evolution, with most teachers (86%) saying they did not know of many internet activities to foster better understanding of evolution. In fact, a wealth of videos and internet activities are available, and models of the skulls of various hominin ancestors are available.

4.7 CONCLUDING REMARKS

Seven instruments were used to investigate the extent of the pedagogical content knowledge of two groups of *Life Sciences* teachers about to teach evolution for the first time. The results of this study suggest that the PCK level of many teachers was insufficient for the effective teaching of evolution.

The data that were analysed in this chapter are summarised and conclusions drawn from the findings are made in Chapter 5.