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

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CHAPTER 4

Results and discussion

4.1 OVERVIEW OF THE CHAPTER

This chapter presents and discusses the research findings for this study. The concerns expressed by *Life Sciences* teachers who attended a series of workshops designed to prepare teachers to teach the topic of evolution, and their needs pertaining to teaching evolution for the first time in 2008, have been analyzed and presented to answer the research questions listed in Chapter 1, section 1.8. As one of the concerns was possible lack of subject matter knowledge, the chapter reports on the accuracy of teachers' perceptions about their knowledge about evolution. The research questions have been used to structure the presentation of results in this chapter, and the information is organized and arranged in tables and graphs so it is more easily accessible.

4.2 PROBLEMS ENCOUNTERED WHEN ANALYZING THE TEACHERS' CONCERNS

When attempting to classify concerns expressed by the *Life Sciences* teachers about teaching evolution in this study, I encountered problems which I anticipate that anyone else doing a study on concerns is likely to experience. Table 10 provides a summary of the problems encountered. In this table I have listed the problems, and further explained each problem and the action taken to deal with it.

Table 10: Problems encountered during classification of concerns

List of problems	Elaboration	What was done
Some responses were difficult to classify as concerns	Some responses were vague and / or not related to the act of teaching, or not worded as concerns. For example, *"My questions that I have would be answered"* [#8.8]; *"1. Greenhouse effects 2. Global warming and pollutions are worrying factor"* [#12.8].	A new category named "difficult to classify" was added under the categories in the coding system developed to analyze the data.
Some responses contained more than one concern	Some responses in a speech bubble contained more than one statement. For example, *"To be sure that my learners feel confident and well prepared. Do my learners need to know time lines & dates"* [#8.I8]; *"Its* (sic) *all new to me, so I dont* (sic) *really know what to expect. From a Christian point of few* (view) *I'm not comfortable with the idea"* [#5.8].	Responses with more than one statement were split, and coded separately.
It was difficult to categorize some concerns in the "informational" or "personal" sub-categories under "self concerns"	Some responses contained elements of two different categories. For example *"I am not yet well equipped to teach it esp in terms of the teaching approach"* [#44.7]. The response could have been coded as "personal" because it was expressed in an egocentric way or "informational" because the teacher knows little about evolution, and requires specific knowledge.	• A set of criteria to help classify each concern was developed. • In my case all the responses that were expressed in an egocentric way (using the word 'I') but requesting more knowledge were categorized in the "informational" category and the responses expressed in an egocentric way but which did not require any specific knowledge were categorized as "personal".

It is important that researchers who study concerns should be more critical when classifying concerns, as an error in one category can call the entire results into question. I therefore believe that it is vital to develop correct categories during data analysis to help reduce challenges affecting validity of the study.

During the process of classifying teachers' concerns two other problems surfaced. The first problem related to words that were incorrectly spelled. For example

> "*Change in their Religious beliefs – young and exceptive* (accepting) *to knew* (new) *knowledge*" [#29.8].

Such problems existed because some teachers who participated in the study were second language speakers, or perhaps time was not sufficient for teachers to proof-read their concerns and correct mistakes. To address the problem during data analysis and reporting, when using quotes from teachers I italicized the direct quotes and put the correct words in brackets, unitalicized, so the sentence made sense, yet original statements were retained.

The second problem related to similar responses written by different teachers who were seated together. They could have been consulting, so the answers were not necessarily their own opinions. We had already anticipated this problem, and two steps were taken at the workshop to prevent teachers talking to each other before responding to the activity-based questionnaires. Firstly, teachers from one school were encouraged to mix with teachers from different schools i.e. to sit at different tables. Although this was done to facilitate networking it had the added benefit that teachers were less likely to discuss their answers with someone they did not know well. Secondly, respondents were encouraged to be as honest as possible. In spite of this I still found some instances which indicated that teachers seated together were consulting with each other, for example:

> "*How much depth should be covered*" [#1.7] and "*I had been worried about the background knowledge, particularly the depth to which we should go*" [#2.7].
>
> "*Concerned – lack of indepth* (in-depth) *knowledge*" [#35.8] and "*Afraid lack of knowledge*" [#36.8].

Unfortunately, nothing could be done at the analysis stage to address the problem, and I just had to bear in mind that it affects validity when a teacher has discussed the problem and lists someone else's ideas. However, they would be unlikely to list something they did not believe, even if the idea **originated** with someone else.

4.3 IDENTIFYING TEACHERS' CONCERNS

The data reported and discussed in this section is an attempt to answer the first aspect of the following research question.

Research question 1: What were *Life Sciences* teachers' concerns and needs regarding having to teach evolution to Grade 12s in 2008, as part of a new curriculum?

Two questions in the first activity-based questionnaire were used to identify teachers' concerns. The first question asked teachers: *How do you feel about having to teach evolution in 2008?* This question was asked at the start of the workshop to get the teachers to think about how they felt about having to teach evolution, so as to avoid immediately focusing on potential negative aspects (their worries or concerns).

4.3.1 Teachers' positive feelings

Ninety-one teachers from both the workshops responded to the first question, and in total 148 comments were made. Of the 148 comments 76 (51%) were positive and came from fifty-two teachers (57% of the sample). Seven main categories and a number of sub-categories of positive feelings emerged from open coding of responses (see Table 11). The percentages in the columns for each workshop are calculated according to the number of teachers attending that workshop. The total percentages are calculated according to the whole sample (i.e. 2007 sample and 2008 sample). Note that when decimal places were totalled in some tables and the final figure rounded off, it was understandably often 1% out. Furthermore, the quotes which follow the table are cited directly and may include spelling and grammatical errors.

Table 11: Summary of teachers' positive feelings about having to teach evolution (n = 52)

Workshop	**WS 1**	**WS 2 (private)**	**WS 2 (gov.)**	**Total**
Number of teachers with positive comments	21	11	20	**52**
Number of comments listed [average no. per teacher]	41 [1.9]	14 [1.2]	21 [1.0]	**76**

Positive feelings about having to teach evolution		**WS 1**	**Total**	**WS 2 (private)**	**Total**	**WS 2 (gov.)**	**Total**	**Whole sample**
Excited …	no specific reason given **(11)**	4 (10%)		2 (14%)		5 (24%)		**39 (51%)**
	because it is a new topic **(12)**	4 (10%)		3 (21%)		5 (24%)		
	at the opportunity **(9)**	5 (12%)		0		4 (19%)		
	to improve learner's knowledge **(7)**	2 (5%)	15 (37%)	1 (7%)	6 (43%)	4 (19%)	18 (86%)	
Happy / glad …	as it is an exciting / interesting topic **(5)**	4 (10%)		0		1 (5%)		**9 (12%)**
	it is the key to understanding biology **(1)**	0		1 (7%)		0		
	to be up to date **(2)**	1 (2%)		1 (7%)		0		
	to discuss evolution of micro-organisms **(1)**	1 (2%)	6 (15%)	0	2 (14%)	0	1 (5%)	
Stimulated	no reason stated **(1)**	1 (2%)	1 (2%)	0		0		**1 (1%)**
Confident	no reason stated **(2)**	1 (2%)	1 (2%)	1 (7%)	1 (7%)	0		**2 (3%)**
Resigned	reason stated **(10)**	4 (10%)	4 (10%)	4 (29%)	4 (29%)	2 (10%)	2 (10%)	**10 (13%)**
Source of opportunity	for teachers to improve knowledge **(4)**	4 (10%)		0		0		**10 (13%)**
	to benefit learners **(2)**	2 (5%)		0		0		
	to change learners' attitudes **(2)**	2 (5%)		0		0		
	to look at creation/evolution controversy **(2)**	2 (5%)	10 (23%)	0		0		
Interesting course		1 (2%)	1 (2%)	0		0		**1 (1%)**
Other positive comments		3 (7%)	3 (7%)	1 (7%)	1 (7%)	0		**4 (5%)**

- **Teachers were excited:** It is interesting to note that just above half (51%) of the positive comments expressed showed teachers were excited about teaching evolution. While 11 comments made did not have specific reasons for excitement, 28 of the comments made included reasons. There were three reasons for teachers' excitement. The most common sub-category, containing

12 comments, indicated that teachers were excited because ***it is a new topic***. Some of the quotes are cited below:

"*Quite excited about new subject matter*" [#6.7];

"*Excited → something new and interesting*" [#14.7];

"*Excited – a different aspect in L.S.* (Life Sciences) *not really touched before*" [#19.7];

"*Excited a new piece of work (interesting work)*" [#20.I8];

"*Excited – new topic, very relevant to the sciences →good to show links thro' ages!*" [#23.I8];

"*Quite excited → dealing with new subject knowledge*" [#26.8];

"*Excited a new area to learn something about*" [#43.8].

The sub-category with the second highest number of comments (i.e. nine comments) showed that the teachers were excited because they saw the topic as an ***opportunity***. In Table 11 there is another category called ***source of opportunity***. The difference between the two is that this first category is about teachers being excited and the reason they gave is that it was an opportunity while the second category is itself that teachers saw the topic as a source of opportunity, for various reasons discussed later in the section. Examples of comments from this sub-category, are associated with their excitement,

"*… broadening my knowledge*" [#6.7];

"*Excited – a new challenge – broadening horizons*" [#28.8];

"*Opportunity to say there is not a conflict between God and Science*" [#45.7];

"*Opportunity to help "unconfuse" people*" [#45.7].

The third sub-category, containing seven comments, mentioned that teachers were excited because they would be ***able to improve learners' knowledge***. Teachers made comments such as

"*Excited to learn with my learners. Bring it on*" [#3.8];

"*Excited to explore examples of evolution with the kids"* [#11.7];

"*Excited to expose learners to various ideas on evolution*" [#17.7];

"*Excited – always loved fossils - can share my passion with learners*" [#28.I8].

Table 11 shows a tie between two categories of positive feelings after "excitement", each with ten comments (13% of the total, in each category).

- **Teachers resigned to the introduction of evolution in *Life Sciences*:** The first category included comments showing that some teachers seemed resigned (accepting) to the introduction of evolution. Examples of comments in this category are

"*Yes I'll be a novice but I'll do my best*" [#5.7];

"*I am ok with teaching evolution. Feeling positive*" [#7.I8];

"*Humble need to do a lot of reading on topic – hopefully will feel more secure at end of workshop*" [23.I8];

"*Quite calm*" [#39.7].

- **Teachers saw teaching of evolution as a source of opportunity:** The second category with ten comments (i.e. 13%) had comments showing teachers saw the introduction of evolution as an opportunity not because they were excited, as discussed earlier, but for different reasons. The reasons provided clustered into four sub-categories. The first sub-category, containing four comments, mentioned teaching of evolution as an ***opportunity for teachers to improve their knowledge***. Teachers made comments such as

  "I will be able to know what evolution is" [#30.7];

  "Chance to consolidate my own ideas on the topic" [#19.7].

  The other three sub-categories each contained only two comments. One sub-category referred to evolution as a ***source of opportunity to benefit learners***. These comments were mentioned by one teacher who said

  "*I think it will be interesting for learners to know about the past v/s the future*" and "*May-be learners will have more understanding of life – how it came about due to time*" [#29.7].

  The second sub-category with two comments, mentioned by two teachers, related to evolution as a ***source of opportunity to change learners' attitudes.*** The two teachers said

  "*A lot of moral conflict for learners, and they get to respect other learners points of views*" [#10.7];

  "*It would change people's attitudes towards all forms of life species*" [#29.7].

  The third sub-category with two comments, also made by two teachers, indicated that the introduction of evolution is a ***source of opportunity to look at the creation/evolution conflict***. The teachers commented

  "*Looking forward to debates that will be triggered – must be handled properly though*" [#18.7];

  "*… as most people are afraid to approach this section as it affect their religious beliefs*" [#29.7].

  It is interesting to note that the 10 comments relating to evolution as a source of opportunity were given at the first workshop, long before the topic of evolution was implemented in Grade 12 (this excludes the four comments listed in the category **excited** relating to the topic of evolution as an opportunity). This workshop took place three months before the end of the academic year prior to implementation, nine months prior to teaching the topic. When the implementation of evolution was on the doorstep none of the teachers at the later workshops saw it as a source of opportunity (see Table 11).

- **Teachers were happy / glad about teaching evolution:** This category had the third highest number of comments, nine (12% of the comments). The comments clustered into four sub-categories. The first, containing five comments, mentioned that teachers were happy because ***evolution is an exciting / interesting topic.*** Teachers made comments such as

"*Happy that, new exciting topics had been introduced into the syllabus*" [#2.7];

"*Interesting topic for kids to debate over*" [#10.7];

"*Feeling good about it, cause is something the learners has to be aware of*" [#16.7].

The second sub-category, containing two comments, referred to teachers being happy ***to be up to date*** with current scientific developments. One teacher explained

"*Glad to be keeping with modern thinking*" [#11.7].

The third sub-category, containing only one comment, had to do with being happy as the teacher would ***be able to discuss evolution of micro-organisms***. The teacher made the following comment

"*Happy to be able to discuss evolution of viral + bacterial pathogens and their impact on resistance*" [#11.7]

It is interesting to note that the fourth sub-category, also containing only one comment, referred to ***evolution as a key to understanding biology.*** This teacher made the comment

"*Pleased – evolution is the key to understanding Biology, and to teach without it in the past has been difficult*" [#2.I8].

This teacher understands that evolution is the theory that serves as a thread that weaves together various aspects of biology.

Other categories relating to positive feelings are shown in Table 9. Because each contains few comments from very few teachers, they are not discussed further.

4.3.2 Teachers' negative feelings

Although many teachers in this study were positive about the teaching of evolution, 47 of the 91 teachers had negative feelings. It should be noted that some teachers expressed both positive and negative feelings. Their responses to the first question resulted in 72 "negative" comments, which was 49% of all the comments. Eight main categories and a number of sub-categories related to negative feelings emerged from the open coding of responses (see Table 12 on the next page).

- **Teachers were anxious:** The most notable finding was that teachers were anxious. Teachers used a variety of words which indicated this (e.g. nervous, worried, afraid, and scared). Twenty-seven comments were expressed in this category, which was 38% of all negative comments. Although four comments did not include reasons for teachers' worries, 23 comments were linked to reasons. The commonest problem (almost half the comments) was related to the teachers' ***lack of knowledge*** (12 of the 27 comments). The other reasons were mentioned in smaller numbers ***potential conflict with faith systems of parents and learners*** (4 comments); ***what approach to use*** (3 comments); ***controversial topic to teach*** (2 comments) and ***never taught it before*** (2 comments). These comments will be discussed later, in section 4.3.4.

- **Teachers were lacking confidence:** Eighteen of the seventy-two comments (25%) referred to teachers' lack of confidence. Examples of comments in this category were

"*It's a new chapter in the curriculum there's no one I'll discuss with so as to be confident in delivering the subject content*" [#4.7];

"*Not confident about the subject matter*" [#6.7];

"*Very unsure! What to present and what not*" [#5.I8];

"*Less confident*" [#17.7].

Table 12: Summary of teachers' negative feelings about having to teach evolution (n = 47)

Workshop	**WS 1**	**WS 2 (private)**	**WS 2 (gov.)**	**Total**
Number of teachers with negative comments	16	9	22	**47**
Number of comments listed [average no. per teacher]	29 [1.8]	14 [1.5]	29 [1.3]	**72**

Negative feelings about having to teach evolution		**WS 1**	**Total**	**WS 2 (private)**	**Total**	**WS 2 (gov.)**	**Total**	**Whole sample**
Feeling challenged in a negative sense	no specific reason given **(2)**	2 (7%)		0		0		**11 (15%)**
	difficult topic for teachers **(3)**	3 (10%)		0		0		
	difficult topic for learners **(1)**	1 (3%)		0		0		
	lack of scientific agreement **(1)**	1 (3%)		0		0		
	because of religious conflict **(4)**	4 (14%)	11 (38%)	0		0		
Anxious / worried / scared / afraid / nervous	no specific reason given **(4)**	2 (7%)		0		2 (7%)		**27 (38%)**
	lack of knowledge **(12)**	3 (10%)		2 (14%)		7 (24%)		
	what approach to use **(3)**	0		1 (7%)		2 (7%)		
	conflicts with faith systems of parents and learners **(4)**	0		2 (14%)		2 (7%)		
	a controversial topic to teach **(2)**	0		0		2 (7%)		
	never taught it before **(2)**	0	5 (17%)	1 (7%)	6 (43%)	1 (3%)	16 (55%)	
Confused	no reason stated **(3)**	1 (3%)		0		2 (7%)		**8 (11%)**
	what to teach **(5)**	2 (7%)	3 (10%)	1 (7%)	1 (7%)	2 (7%)	4 (14%)	
Angry		1 (3%)	1 (3%)	0		0		**1 (1%)**
Frustrated		1 (3%)	1 (3%)	0		1 (3%)	1 (3%)	**2 (3%)**
Lacking motivation		2 (7%)	2 (7%)	0		1 (3%)	1 (3%)	**3 (4%)**
Lacking confidence		4 (14%)	4 (14%)	7 (5%)	7 (50%)	7 (24%)	7 (24%)	**18 (25%)**
Difficult to classify		2 (7%)	2 (7%)	0		0		**2 (3%)**

- **Teachers were feeling challenged in a negative way:** This category provided the third highest number of comments, 11 of the 72 comments (15%). The comments in this category clustered into five sub-categories (see Table 12), although there were few comments in each sub-category. Of the 11 comments two comments did not have reasons and the nine other comments had specified reasons. The commonest challenge (almost half the nine comments) was that evolution ***conflicts with teachers' and learners' religious beliefs***. Teachers made comments such as

  "*The most disturbing challenge is one's belief against science, regarding evolution of man*" [#21.7];

  "*It may be difficult to teach because it may differ from what we know and the learners know about creation*" [#40.7];

  "*Challenged I am a staunch Christian*" [#44.7].

  Teachers who perceive evolutionary theory to be in conflict with their personal religious beliefs may be coming from a culture where people simply do not believe in evolutionary accounts, and therefore evolutionary theory is unbelievable to them. It is important that the teachers are made

aware that many people from many major religious groups (e.g. Christianity, Judaism and Islam) have no difficulty with evolution. This is often because they hold the idea that science and religion constitute different but complementary forms of knowing (Scott, 2000), and can thus accommodate both their religious beliefs and what scientists say about evolution.

The second sub-category, containing three comments, referred to evolution as a ***difficult topic for teachers***. Teachers made the following comments

"*Difficult to explain especially the fossil fuel part*" [#4.7];

"*I think it will be difficult for an educator to teach*" [#21.7];

"*Problems in giving example*" [#27.7].

It is interesting to note that all the comments in the category of "feeling challenged in a negative way" came from the August 2007 workshop (see Table 12). This workshop took place nine months prior to the teaching of evolution. However, when the teachers were four months prior to teaching evolution or had already started teaching it, no such comments arose from the later workshop.

- **Teachers were confused:** This category had the fourth highest number of comments (i.e. 8 comments). The comments clustered into two sub-categories, the first (containing 2 comments) did not provide specific reasons why teachers were confused. The second (containing 6 comments) mentioned that the teachers were confused because they ***did not know what to teach***. Examples of comments made in this sub-category were

  "*Very confused do not know what to teach*" [#29.8];

  "*Not sure about it. Since it touches different learning areas*" [#39.7].

Other categories relating to negative feelings are shown in Table 12. Because each contains few comments from very few teachers, they are not discussed further.

Horsely and Loucks-Horsely (1998) say that although having negative feelings may appear to be indicative of refusal or rejection of an innovation, their legitimacy should not be dismissed, because a person with negative feelings is driven by a need for support as the person comes to grips with something new. This has important implications for anyone trying to support teachers through curriculum changes e.g. by in-service training.

4.3.3 Feelings continuum about teaching of evolution

In summary, fifty-two teachers in this study made positive comments about teaching evolution, and forty-seven teachers were negative about teaching evolution. Some teachers made positive and negative comments so the number of the two groups does not total 91 (the number of teachers responding). Of those supporting the teaching of evolution, some thought the topic was exciting, stimulating, a source of opportunity, while others were glad about the idea of teaching evolution and were confident and accepting of it, as shown in Table 11. The teachers with negative feelings about

teaching evolution were anxious, lacked confidence and motivation, or were confused and angry (see Table 12). Based on the wording of the responses these feelings can be placed along a continuum from very positive feelings at one end to very negative feelings at the other end of the spectrum, with some fairly neutral feelings in the middle. Table 13 provides an overview of the positive/negative feelings continuum, putting varying degrees of acceptance to rejection along the continuum.

Table 13: The positive/negative feelings continuum

Very positive ↕	Confident	**Very positive** (42 comments)
	Excited	
	Stimulated	
	Happy/glad	**Positive** (8 comments)
	See it as an opportunity	**Neutral** (21 comments)
	Over due	
	Feeling challenged in a negative sense	**Slightly negative** (32 comments)
	Lacking confidence	
	Lacking motivation	
	Anxious/afraid	
	Confused	**Very negative** (11 comments)
	Frustrated	
Very negative	Angry	

4.3.4 What the teachers were worried about

The previous section discussed general comments voiced by the teachers, without any particular focus. The teachers were then asked: *"If you have any worries or concerns about teaching evolution in 2008, and have not yet explained them above, please add them here".* The second question was asked as it focused on the teachers' **concerns,** which was a major focus of the study. This information is important so relevant in-service training aimed at addressing teachers' concerns can be offered. Ninety-one teachers from the 2007 and 2008 workshops voiced their worries, and in total 226 comments about concerns were made (the total number of comments included **concerns** stated in the first question as well as those elicited by the second question). Ten main categories and a number of sub-categories of concerns emerged from the open coding of the responses (see Table 14 on the next page).

The major source of concern (113 comments, or half of the 226 concerns) related to teachers' inadequate knowledge. The comments clustered into three sub-categories.

- **Teachers' content knowledge lacking:** The first sub-category, containing 49 comments, had to do with teachers' lack of content knowledge. Although 22 of the 49 comments did not specify what content knowledge the teachers lacked, 27 comments specified what they were worried about. The commonest concern, almost half the comments, was related to the ***teachers' content knowledge lacking about evolution*** (25 of the 49 comments). Teachers made comments such as

  "*I want to know how it all started and why people connect this whole concept with us as humans, today*" [#5.8];

  "*Apprehensive: as I don't know as much about evolution as I would like to. Feel I need more experience*" [#7.8];

"*Concerned that it is such a wide topic* [assume evolution] *– so much to read up on – will I ever know enough*?" [#9.I8];

"*A bit concerned about my knowledge of human evolution*" [#11.I8];

"*Why other animals like cow and dogs don't evolve*" [#21.8];

"*Not knowledgeable enough to teach the content* [assume evolution] *in an unbiased manner*" [#27.8];

Table 14: Summary of teachers' concerns about having to teach evolution (n = 91)

Workshop	**WS 1**	**WS 2 (private)**	**WS 2 (gov.)**	
Number of teachers responding	30	20	41	(n = 91)
Number of concerns listed [average no. per teacher]	63 [2.1]	59 [2.9]	104 [2.5]	226

				Total		**Total**		**Total**
No worries **(10)**	no concerns stated **(8)**		0		5 (8%)		3 (3%)	
	said they had no concerns, then stated some **(2)**		0		2 (3%)	7 (12%)		3 (3%)
Concerns relating to...								
inadequate knowledge **(113)**	teachers' content knowledge lacking (**49**)	about evolution **(25)**	7 (11%)		7 (12%)		11 (11%)	
		about religion **(2)**	1 (2%)		1 (2%)			
		about unamed content **(22)**	3 (5%)	11 (17%)	5 (8%)	13 (22%)	14 (14%)	25 (24%)
	teachers unsure about what to teach (**25**)	where to start **(2)**	1 (2%)				1 (1%)	
		what to cover, when **(10)**	3 (5%)		4 (7%)		3 (3%)	
		what depth to teach at **(10)**	3 (5%)		6 (10%)		1 (1%)	
		what will be assessed **(3)**	1 (2%)	8 (13%)	2 (3%)	12 (20%)		5 (5%)
	unsure what teaching approach to use (**39**)	for specified task **(12)**	4 (6%)		2 (3%)		6 (6%)	
		no task specified **(6)**	2 (3%)				4 (3%)	
		to handle the controversy **(21)**	1 (2%)	7 (11%)	8 (14%)	10 (17%)	12 (12%)	22 (21%)
controversial nature of the topic **(49)**	evolution conflicts with religion **(20)**		8 (13%)		3 (5%)		9 (9%)	
	difficult for learners / conflicts with beliefs **(8)**		3 (5%)				5 (5%)	
	conflicts with own beliefs **(8)**		1 (2%)				7 (7%)	
	policy conflicts in Church schools **(3)**				3 (5%)			
	dealing with parents' beliefs **(10)**		3 (5%)	15 (24%)	3 (5%)	9 (15%)	4 (4%)	25 (24%)
lack of resources **(12)**	textbooks **(1)**		1 (2%)					
	laboratory **(2)**		2 (3%)					
	computers **(1)**		1 (2%)					
	teacher support material **(4)**		2 (3%)				2 (2%)	
	general **(4)**		1 (2%)	7 (11%)	1 (2%)	1 (2%)	2 (2%)	4 (4%)
learners **(10)**	learners' attitudes **(5)**		3 (5%)		1 (2%)		1 (1%)	
	learners' readiness **(3)**		1 (2%)		1 (2%)		1 (1%)	
	learners having misconceptions **(2)**			4 (6%)	1 (2%)	3 (5%)	1 (1%)	3 (3%)
lack of time **(4)**	lack of time to prepare themselves **(2)**		2 (3%)					
	lack of teaching time / curriculum too full **(2)**		1 (2%)	3 (5%)			1 (1%)	1 (1%)
feeling inadequate (**13**)	teacher's lack of confidence **(12)**		2 (3%)		3 (5%)		7 (7%)	
	unprepared / needing help **(1)**			2 (3%)		3 (5%)	1 (1%)	8 (8%)
lack of support for teachers (**4**)			1 (2%)	1 (2%)			3 (3%)	3 (3%)
other **(5)**	lack of relevance (**2**)				1 (2%)		1 (1%)	
	teachers' attitudes (**2**)		1 (2%)				1 (1%)	
	timing too late at Grade 12 level (**1**)		1 (2%)	2 (3%)		1 (2%)		2 (2%)
difficult to classify (**6**)			3 (5%)	3 (5%)			3 (3%)	3 (3%)

"Concerned – lack of indepth knowledge" [#35.8];

"*Learners could also ask if evolution still happen in nowadays, if not why?*" [#36.7];

"Is evolution continuing? Can new 'organisms' develop from humans?" [#37.7];

"Scared to teach something I am not sure of. I've never done evolution at school even in college training" [#40.8].

Teachers showed a range of degrees of concern about their lack of knowledge, from "a bit concerned" or "apprehensive" to "worried" or "scared".

Research shows that one consequence of teachers' lack of thorough knowledge of evolutionary theory has been that they de-emphasize it when they teach, or they omit it altogether (e.g. Rutledge and Mitchell, 2002; and Wuerth, 2004). Shulman (1986) says that for teachers to be effective in their teaching, they need to master the subject matter they are required teach. Improving teachers' content knowledge therefore needs to be a focus of in-service training.

Other reasons were mentioned in smaller numbers. ***Lacking knowledge about religions*** (two comments) for example

"*Worried – my knowledge from different religious aspects very limited*" [#19.7].

Smith (1994) points out that in most cases **students** bring a wide range of religious beliefs to class which may hinder conceptual understanding. However, he warns that a lack of knowledge of various religious beliefs on the side of the **teacher** would result in learners not achieving a meaningful understanding of evolutionary principles. This has important implications for in-service training designers in their attempt to support teachers.

- **Unsure what teaching approach to use:** The second most frequent sub-category in the 'inadequate knowledge' category related to ***teachers' uncertainty about what teaching approaches to use*** when teaching evolution (39 comments). Although six comments did not mention a specified task, 33 comments spelled out a specific aspect they did not know how to handle. The commonest concern (just above half the comments) was related to the teachers' uncertainty about what approach to use when ***handling the controversy*** (21 of the 39 comments). Most of the comments seem to apply to the teaching approach. For example

  "*Unsure about dealing with religious issues as I am aware that it could become a problem in class when it comes to different religions*" [#4.8];

  "*Am uncertain about the approach – if it can be done from a Christian perspective. It is a challenge*" [#17.8];

  "*What do I do if I encounter problems with different religious groups*" [#22.7];

  "*Scared → will I be able to answer / handle the 100's of Q's I anticipate being asked by learners*" [#23.I8];

  "*Religious issue & stepping on toes*" [#24.I8];

  "*Learners are going to want to debate and argue the issue. Do we have enough knowledge to facilitate these discussions*" [#36.8].

Some of the comments had to do with 'not hurting learners', 'coping with concerns of parents or communities' and 'teacher's own views'. Teachers made comments such as

> "*What if sensitive learners react very negatively on it? What will I do to calm the storm?*" [#2.8];
>
> "*Nervous - conflicting with the faith system of some learners*". [#2.I8];
>
> "*I come from a very faith based town so I am concerned about how I can answer the questions from creationism children. I certainly do not want to cause unhappiness*" [#21.I8];
>
> "*Not adequately prepared to deal with criticism from parents and religious groups*" [#27.8];
>
> "*Being able to control my own belief system and not influence my pupils in that way*" [#33.I8].

Teachers need to be equipped with suitable teaching approaches that will help to bridge the false dichotomy that is so persistent, of evolution versus religion. The use of appropriate strategies needs to be a focus of in-service training provided for teachers.

The second commonest concern regarding what teaching approach to use was related to the teachers' uncertainty about what approach to use for a ***specified task*** (about a third of the comments on what approach to use – i.e. 12 of the 39 comments). Most comments referred to learners' attitudes and how the teachers can maintain interest or enjoyment about the topic of evolution. Teachers made comments such as

> "*With learners present negative attitudes → how can we maintain interest*" [#14.7];
>
> "*I feel that I have not got knowledge to explain evolution to the learners in a way that will make them enjoy it*" [#34.8];
>
> "*Getting learners to understand and enjoy the topic*" [#41.8].

Two comments seem to apply to a suitable approach to use to convince learners to accept learning about evolution. Two teachers commented

> "*How do I convince people around me that that E* (evolution), *is to the benefit of everyone*" [#9.8];
>
> "*The approach to use to convince learners*" [#27.7].

Only two comments dealt with actual content. Comments made were

> "*Dealing with misconceptions learners have*" [#24.I8];
>
> "*How to go about not confusing learners*" [#29.8].

According to Shulman (1986) pedagogical content knowledge is important in teaching, as it focuses on particular content-appropriate approaches that are best suited to teaching specific topics so that pupils understand the fundamental concepts involved. In the case of evolution such content-appropriate approaches include strategies for teaching controversial topics as well as the need to develop attitudes of open-mindedness and tolerance of other viewpoints.

- **Unsure about what to teach:** Twenty-five of the comments in the 'inadequate of knowledge' category (i.e. 22% of them) were associated with not knowing what to teach. Table 12 illustrates four matters which were a source of concern for teachers. The first two most common matters had 10 comments each. The first matter mentioned was that teachers were concerned about ***what to cover and when***. Teachers made comments such as

  "*Very unsure! What to present and what not*" [#5.I8];

  "*As long as we are given specific detailed information on what is required then I have no worries and concerns*" [#18.7];

  "*I want to know what is expected at Grade 12*" [#30.7];

  "*Scope – what to teach*" [#33.I8];

  "*It is a lot of work. What must I do and what not!*" [#44.8].

  Before the new *Life Sciences* curriculum was implemented, a Learning programme guideline Grade 10 – 12, dated November 2005 but issued to Gauteng Department of Education teachers in 2007, was issued to schools to guide *Life Sciences* teachers on what to cover (Gauteng Department of Education, 2007). The guidelines were difficult to follow because of the way the content was laid out in it (see Chapter 1, p.5), which caused a lot of confusion. For an innovation to be a success, carefully developed guidelines with sequenced concepts to be covered when teaching specific topics (such as evolution) are essential. Carefully planned guidelines provide practical guidance to teachers and "*assist teachers to plan for sequenced learning, teaching and assessment … so that all Learning Outcomes in a subject are achieved in a progressive manner*" (Gauteng Department of Education, 2007, 3).

  The second matter with 10 comments related to uncertainty about ***what depth to teach at.*** Examples of comments made were

  "*How much depth should be covered*" [#1.7];

  "*I had been worried about the background knowledge, particularly the depth to which we should go*" [#2.7];

  "*Anxious – haven't taught it before: depth of the content*" [#3.I8];

  "*What is essential for learners to know and what parts are simply for interest sake*" [#10.7];

  "*To what extent and how much detail to give through as not all textbook are complete and are of the same standard*" [#19.I8].

  A carefully planned work schedule which indicates the depth to teach at and the sequence in which the content should be presented should be provided at this stage to guide teachers on what to include in their lesson plans, but no such document was provided for the teacher when the new FET curriculum was first implemented in 2008. The new Curriculum and assessment policy statement (CAPS) document provided in 2011, when the *Life Sciences* curriculum statements were revised for the second time since it was implemented, provides an exact weekly schedule of when and what content areas must be covered (Department of Basic Education, 2011), but guidelines on detail are left to textbook writers.

Whilst content is spelled out the document does not show that evolution permeates other sections, for example evolutionary changes in the phyla to be covered (Department of Basic Education, 2011).

The third matter that teachers were unsure about was ***what will be assessed*** (3 comments). The teachers made the following comments:

"*What type of questions should we expect*" [#14.7];

"*How examined*?" [#20.I8];

"*Type of questions in exam – if answer will they be penalized*?? *Will it require a definite opinion or not*" [#29.I8].

From informal talks with *Life Sciences* teachers in a cluster meeting in one school district in Gauteng, it appeared that model exam questions are useful as they expose teachers to a wide variety of questions likely to be asked during exams, and help teachers to understand the examiners' way of thinking. The teachers assert that if model exam questions are used effectively in class they help boost teachers' and learners' confidence, but warn that too much dependence on them might compromise other aspects relating to a specific topic. This has implications for subject facilitators and in-service providers. In their attempts to support teachers, support materials developed for teachers should include exemplar question papers. Such exemplars were provided during the first term in 2008.

The fourth matter mentioned was that teachers were unsure about ***where to start*** (2 comments).

"*Where do we start*" [#14.7];

"*Not knowing the objective of the lesson*" [#22.8].

As discussed above, a carefully planned work schedule would guide the teachers on where to start. The new CAPS document has included information on timing to guide teachers, and spells out the sequence of content to be covered from Grade 10 to 12.

Concerns relating to lack of knowledge need to be brought forward and explored so people involved in supporting teachers can begin to design in-service training that better supports the teachers in their teaching of evolution, while at the same time making the change process less threatening.

- **The controversial nature of the topic:** The second major category of concerns (21% of those listed) related to the controversial nature of the topic of evolution. The research literature from America and United Kingdom shows this to be a major problem when it comes to the teaching of evolution (for example, Rutledge and Warden, 2000; Wuerth 2004; and Moore, 2008). The comments clustered into five sub-categories, the first sub-category (containing 20 out of the 49 comments) simply mentioned the ***potential evolution/creation conflict***. The majority of comments were general. For example

  "*It is against Christian religion belief*" [#4.7];

  "*Christainity vs evolution*?" [#9.8];

"*I am worried about evolution in a class because I know, it will be as if it clashes with some religions especially Christians*" [#16.7];

"*CONFUSED – conflicting creation & evolution beliefs*" [#32.I8];

"*Evolution could be in conflict with what learners believe according to their Christianity*" [#40.7].

Only two comments were specific about where the conflict lay.

"*This subject bring an element of conflict as far as religion and belief. Christianity say* (s) *God is the creator and science proves that man has evolved"* [#5.7];

"*Where does God link with the near man as it says He made man with His own image*" [#38.8].

Two of the teachers were worried about the implication of the diversity of religions in the classroom. The teachers commented

"*Different religious groups at my school. Won't it spark fire?*" [#2.8];

"*Diverse religious backgrounds and a lack of basic scientific knowledge presents a barrier. Many Gr. 11 think that the world is ± 1000 years old! explaining evolution can be difficult with many students who are limited in their thinking*" [#11.7].

The second sub-category, containing 10 comments, related to ***parents' beliefs*** – a very delicate, sensitive and touchy matter according to overseas research into the teaching of evolution (Wilbert and Rusch, 1984; Asghar, Wiles and Alters, 2007). Examples of comments in this sub-category were

"*Nervous - conflicting with the faith system of some parents*" [#2.I8];

"*Concerns – parents vs Catholic ethos*" [#3.I8];

"*I have no major worries as such, maybe what would be a bigger problem are parents quering* (querying) *the importance of such a topic in Grade 12 or for that matter in Life Sciences syllabus*" [#4.I8];

"*Even my headmaster has some concerns as it might create a problem amongst the parents not wanting this topic to be taught*" [#4.8];

"*Parents will think I am teaching their children about them being baboons and they have concerns about that*" [#38.7];

"*I'm concerned about how religious and uninformed parents would react to the theme*" [#39.8].

The third sub-category shared the same number of comments with the fourth sub-category (eight comments each). The third sub-category relates to ***problems learners would experience when learning the concept of evolution***, for example

"*Can confuse learners. Creation vs Evolution*" [#11.8];

"*What about Christian learners*" [#18.8];

"*I think it's going to cause a very incredible confusion to learners*" [#21.7];

"*Scared about beliefs of learners"* [#24.8];

> "*Teaching evolution could confuse learners in that, biblically God created everything on earth*" [#36.7].

Asghar, Wiles and Alters (2007) point out that being aware of learners' religious concerns with evolution at an early stage is crucial to better address learners' concerns and thus facilitate understanding. Therefore, all teachers of evolution should be adequately prepared to consider these concerns during their teaching so learners achieve meaningful understanding of evolutionary theory.

The fourth sub-category (containing 8 of the 49 comments) had to do with ***conflict between teachers' own religious beliefs and evolution***. Teachers made comments such as

> "*I am a Christian I belief* (believe) *I have been created. That means I may have an interference of my belief whilst teaching this section"* [#5.7]*;*
>
> "*From a Christian point of view I am not comfortable with the idea*" [#5.8];
>
> "*My concern is evolution against religion. Because as a Christian, I know man is created by God*" [#21.8];
>
> "*Religion issue. Committed Christian*" [#29.8].

One teacher who was worried that evolution conflicts with her own beliefs elaborated, saying

> "*It contradicts with genetics especially when we talk of mitochondrial DNA inherited from mitochondrial Eve it contradicts with my belief and already there is a lot of argument and debates in my class*" [#20.8].

The teacher seems not to understand that knowledge of genetics contributes to our understanding of many aspects of life sciences, including evolution (i.e. it is a vital prerequisite topic underpinning evolution), and that genetics does not contradict evolutionary theory. When scientists use the term "mitochondrial Eve" they are using the term metaphorically to refer to the maternal line.

The fifth sub-category referred to the ***problems the topic of evolution may cause in religious schools***. Although only three comments were expressed in this sub-category they showed that teachers from the church-schools were anticipating problems regarding the teaching of evolution. Of the three comments made, two comments were made by teachers from the same school. Three teachers commented

> "*Christian school that does not hold to evolutionary theories – clearly creationism. Clear policy on this*" [#29.I8];
>
> "*Being a Christian school we need to focus on Creation theory in depth. We need help in this regard*" [#31.I8];
>
> "*We are required by our Headmaster to present an alternative "Creation" viewpoint to evolution – we need HELP!!*" [#32.I8].

The concerns relating to the controversial nature of the topic are a result of a commonly held misconception that religion clashes with evolution, a perception that tends to be reinforced by the mass media. Scott (2000) warns that the false dichotomy often leads to a generalization that creationists believe in God and evolutionists are atheist. This might be an indication that

members of the public, including teachers, are not aware that individuals from many denominations (e.g. Anglican, Methodist, Lutheran, Roman Catholic, Presbyterian, Disciples of Christ, Judaism) and many professors of theology do not see evolutionary theory as conflicting with their beliefs. Some members of these denominations have signed a letter that endorses that the discoveries of modern science and religion may coexist. When I accessed this letter on the 10th February 2011 the Christian Clergy letter had 12,710 signatures, the Jewish rabbi's letter had 473 signatures, and Unitarian Universalist clergy letter had 234 signatures collected. The letters warn that to treat evolutionary theory as *"one theory among others is to deliberately embrace scientific ignorance and transmit such ignorance to our children"*. The letter, signed by Christian clergy, Jewish rabbis and Unitarian Universalist clergy, can be found on the internet at www.butler.edu/clergyproject/Christian_Clergy/ChrClergyLtr.htm. One way to address the misconception is to make teachers who are required to teach about evolution aware of the range of philosophical beliefs about evolution and religion, using the creation/evolution continuum by Scott (2000). This continuum was used as the basis of one of instruments of the study (see Appendix C6), the teachers did the activity but data were not collected at the workshop because of our ethics-related concerns about teachers sharing this very personal information.

- **Feeling inadequate:** The third most common category of concerns, containing 13 comments, referred to teachers feeling inadequate about teaching evolution. The first sub-category (containing 12 comments) had to do with ***teacher's lack of confidence***. Teachers made comments such as

  "*Still a bit unsure! Will feel more confident if I really know what is important in my textbooks*" [#8.I8];

  "*Not sure what is waiting for me*" [#13.8];

  "*Unsure, not enough confidence as I am not sure what questions to expect from learners*" [#16.8];

  "*Not confident*" [#19.I8];

  "*Worried whether will I ever manage to deliver in class*" [#23.8];

  "*Will I be able to make it without any problems*" [#28.7];

  "*Insecure never taught this before*" [#36.8];

  "*Not sure whether my teaching will be more effective*" [#42.8].

  The second sub-category (with only one comment) dealt with being ***unprepared and needing help***. The teacher commented

  "*Help – need some structured advice – textbooks vary a lot*" [#28.8].

  Concerns relating to feeling inadequate are an indication that these *Life Sciences* teachers had not been adequately trained to handle the topic of evolution in class, and they needed help. Therefore, the concerns in this category need to be brought to the forefront and looked at more carefully so relevant professional support is given to teachers.

- **Lack of resources:** The fourth highest category of concerns, containing 12 comments (5% of those listed), related to ***lack of resources***. A small number of teachers mentioned different things, some of which did not seem pertinent specifically to the teaching of evolution. While four of the 12 comments were ***general***, eight comments were specific. Four matters emerged from the eight comments. The first matter related to ***teacher support material*** (four comments). Sample quotes from teachers include

  "*Will department also provide information packages on evolution*" [#14.7];

  "*Confused – subject guidelines*" [#36.8];

  "*Will I have resources available except having to visit Museums etc*." [#38.7].

Other matters relating to 'lack of resources' are shown in Table 14, were mentioned by few teachers, and included computers, laboratory, and textbooks. It was not clear how the first two relate to teaching of evolution.

4.4 IN WHAT 'STAGE OF CONCERN' DO TEACHERS' CONCERNS CLUSTER?

Concerns theory asserts that individuals have different kinds of concerns about their involvement with change at different times during an innovation. Being aware of the types of concerns teachers have, and addressing them, is important so those involved in managing the change process can begin to design relevant intervention programmes that better support teachers in their teaching of evolution. Hall and Hord (2006) point out that early concerns during times of innovation tend to be unrelated to the innovation, and then become egocentric (i.e. concerns tend to cluster in the 'non-concerns' then 'self-concerns' categories). These authors, as well as Fuller (1969), warn that unless these concerns are resolved, teachers' concerns may not progress from 'self concerns' to 'task concerns' and 'impact concerns', which are extremely important in the classroom. It is important that 'non-concerns' and 'self-concerns' are addressed in early in-service workshops, if teachers are to be helped to move on to consider the impact of an innovation on learners.

Table 15 summarizes the number of comments which were categorized in each 'stage of concern'.

Table 15: Stages of concern associated with 226 comments from 91 teachers

Stage of concern			**WS1**	**Total**	**WS2** (private)	**Total**	**WS 2** (gov.)	**Total**
non-concerns **8** (4%)	unrelated	8	6	**6** (9%)	0	**0**	2	**2** (2%)
self concerns **118** (52%)	informational	74	26		23		25	
	personal	44	6	**32** (49%)	9	**32** (61%)	29	**54** (57%)
task concerns **37** (16%)	how to do it	37	12	**12** (18%)	**9**	**9** (17%)	16	**16** (17%)
impact concerns **49** (22%)	consequence	49	15		11		23	
	collaboration	0	0		0		0	
	refocusing	0	0	**15** (23%)	0	**11** (22%)	0	**23** (24%)
Total **212**				**65**		**52**		**95**
Unclassifiable **6**				3		0		3
No worries **8**				0		5		3

4.4.1 Non-concerns

Of the 226 comments analyzed for this study eight comments were judged to be 'non-concerns' as they did not apply specifically to the teaching of evolution. Example of the quotes from the teachers include

"*Concerned about resources available, especially for practical work*" [#2.7];

"*We hardly have a laboratory*" [#5.7];

"*Unavailability of resources*" [41.8].

The teaching of evolution is not reliant on having a computer laboratory or doing traditional practical activities in the laboratory. Mashalaba and Sanders (2003), in analyzing the types of activities which can be used to promote learning in biology, identified three categories of tasks (practical activities, text-based activities, and communication tasks). The authors point out that text-based activities (e.g. using diagrams, photographs, and text) can facilitate learning if activities are appropriately designed and suitable questions are asked. The Grade 12 new *Life Sciences* textbooks, which were displayed at the workshops, make extensive use of such activities in the module on evolution. Further practical activities for modeling the process and mechanism of evolution can be done by using everyday objects from home such as newspaper, pegs, hair clips, pinchers, beans, play dough, etc., and these were used at the workshops.

4.4.2 Self-concerns

As predicted with a new innovation, the majority of the concerns (52%) fell into the 'self-concerns' stages, which Fuller (1969) categorizes as 'early concerns'. Most of the 'self-concerns' (74 comments, or 33% of all the concerns) related to the need for more content-related information as well as the need to find out more about appropriate teaching strategies, which Hall and Hord (2006) would categorize as 'informational'. The concerns relating to lack of information have already been discussed in the previous section. When informational concerns are intense it is important for in-service providers to pay attention to a warning from Hall and Hord (2006) not to inundate teachers with information that may overwhelm them. Hall and Hord therefore recommend that teachers be given small pieces of relevant information at a time. These should clearly explain what is required of teachers, and should be repeated across time.

The 44 remaining self-concerns (19% of all the concerns) were classified as 'personal' as they were worded in an egocentric way, often expressing fears or lack of confidence in their abilities to teach evolution. For example

"*<u>Afraid</u> – I might not do justice to the topic*" [#3.8];

"*Will I be able to answer all the questions*" [#11.8];

"*So my worry is how I am going to tackle this problem*" [#16.7];

"*Nervous I do not know enough about it*" [19.I8];

"*Worried whether I will ever manage to deliver in class*" [#23.8];

"*Will I be able to make it without any problems*" [#28.7];

"*I feel that I have not got knowledge to explain evolution to the learners*" [#34.8];

"*I am not yet well equipped to teach it esp in terms of the teaching approach*" [#44.7].

The concerns reflect the teachers' uneasiness regarding the teaching of evolution, and may prevent the teachers from looking at the inclusion of evolution in the curriculum with any degree of objectivity. One way to alleviate such concerns is providing teachers with appropriate resources and ideas, and modeling best practice during in-service training. A start was made on doing this at the workshops.

4.4.3 Task concerns

Only 16% of the concerns were categorized as 'task concerns'. Such concerns are an indication that teachers are struggling with how-to-do-skills (Hall and Hord, 2006). Teachers made comments such as

"*The good approach to use, is a worry*" [#2.8];

"*Not enough time to teach the subject because Matric syllabus is huge and demanding*" [#5.7];

"*So my worry is how I am going to tackle this problem to show learners that it is something that they should learn*" [#16.7];

"*Dealing with misconceptions learners have*" [#24.I8];

"*How am I going to introduce this to learners*" [#26.7];

"*How to go about not confusing learners*" [#29.8];

"*If not taught properly it will leave students very confused*" [#44.7];

"*It is a lot of work. What must I do and what not!*"[#44.8].

When task concerns are intense in-service training should focus on providing teaching strategies to equip teachers to cope with the challenges they face. In the case of teaching evolution, the new approaches that teachers are expected to use in class should include a variety of activities which can be role-modelled and discussed during in-service workshops so as to resolve task concerns. Sweeny (2003) and Hall and Hord (2006) warn that task concerns are not resolved quickly. Therefore support given to teachers should be ongoing until teachers master the skills.

4.4.4 Impact concerns

It is interesting to note that 49 of the concerns (i.e. 22% of all the concerns voiced) are 'late concerns', which was more than would be expected at the early stages of implementation of a new curriculum. The concerns focused more on the learners and were categorized as 'impact concerns'. Impact concerns typically indicate great concern about "*improving the impact of the innovation on clients/students*" (Hall and Hord, 2006:140). Example of the quotes from the teachers include

"*What if 'sensitive' learners react very negatively to it*?" [# 2.8];

"*What will I do to calm the storm*?" [#2.8];

"*Know that learners and their parents may be upset*" [#19.7];

"*How to go about not confusing learners*" [#29.8];

"*Being able to control my own belief system and not influence my pupils in that way*" [#33.I8];

"*Teaching evolution could confuse the learner in that, biblically God created everything on Earth*" [#36.7];

"*Getting learners to understand and enjoy the topic*" [#41.8].

The greater number of impact concerns than expected could be because the religion/evolution controversy is something predicted to raise people's anxieties (i.e. to have an impact). Hall and Hord (2006) point out that 'impact concerns' are desirable as they indicate that teachers are taking change positively and are willing to learn alternative ways of approaching change so as to do better. Facilitators are warned to take time when resolving these concerns, as failure to address concerns raised at this stage, may encourage teachers to regress to earlier stages of concern (Hall and Hord, 2006).

It was worrying, but not unexpected at this early stage of the innovation, that none of the concerns expressed by the teachers clustered into the two highest stages of concern (i.e. collaboration and refocusing stages). Collaboration and refocusing are important in helping teachers become more proficient. This suggests that in-service training should provide early opportunities to resolve early concerns, promoting movement to higher levels of concerns, which will improve teachers' professional practices.

From the perspective of concerns-based theory, concerns about innovations appear to be developmental in that earlier concerns must be first resolved (lowered in intensity) before later concerns emerge. It is vital that in-service providers address teachers' early concerns, rather than placing such emphasis on students' achievement during the early stages of an innovation. Appropriate training, sufficient time and paying attention to teachers' concerns, may promote success of an innovation (Hall, George and Rutherford, 1979).

4.5 IDENTIFYING THE TEACHERS' NEEDS

4.5.1 The teachers' needs

The teachers were asked: *"What support do you feel you need in order to feel confident about teaching evolution in 2008?"* This question was asked as it focused on the teachers' needs, the second major focus of the study. This information is important to help in-service providers recognize what the teachers do not know, and believe they need help with, so in-service training can be tailored to meet their needs. Twenty-eight teachers from the 2007 and 2008 workshops completed the whole questionnaire, but four teachers who returned the questionnaire did not respond to this question. Because not all the teachers were there during the excursion, when this questionnaire was collected, the samples were smaller for this analysis than the samples in the previous section. I therefore totalled the responses rather than reporting them separately as I have done up to now, and in total 47 comments were made. Five main categories and a number of sub-categories of needs emerged from the open coding of the responses (see Table 16 on the next page).

Table 16: Summary of teachers' needs about having to teach evolution (n = 24)

	WS 1 and 2
Number of teachers responding	24
Number of needs listed [average no. per teacher]	47 [1.9]

Teachers' needs to teach evolution			**WS 1 and 2**
No answer			4 (9%)
Support material for teachers **(33)**	unspecified teaching aids		2 (4%)
	visual aids **14 (30%)**	charts / posters	5 (11%)
		videos / CDs / DVDs	5 (11%)
		models	3 (6%)
		unspecified visual aids	1 (2%)
	assessment material **9 (19%)**	question papers	4 (9%)
		rubric and memos	2 (4%)
		unspecified assessment activities	3 (6%)
	worksheets		3 (6%)
	educator's guides		2 (4%)
	reading material		2 (4%)
	internet sites		1 (2%)
Support material for learners **(5)**	textbooks		4 (9%)
	study guides		1 (2%)
Help with improving knowledge **(4)**	Content		3 (6%)
	religious beliefs		1 (2%)
Support in terms of in-service training **4 (9%)**			4 (9%)
Does not answer the question **1 (2%)**			1 (2%)

Note: Respondents may have more than one need in a category, so frequencies may not tally to the sample size

The major category of needs (33, or nearly three quarters of the 47 comments) had to do with support material for teachers. The comments clustered into seven sub-categories. The first sub-category containing two comments had to do with the need for ***teaching aids***. However, the teachers did not specify the teaching aids they needed.

The second sub-category (with the highest number of comments, 14) showed that the teachers needed ***visual aids*** of various types, as shown in Table 16. Of the four listed one was unspecified. The first two types mentioned had 5 comments each. The first type related to ***charts / posters***. Teachers made comments such as

"*Using material like charts*" [#27.7];

"*Learning support material such as posters*" [#39.7];

"*Support with learning material such as posters on how human kind started until there be a different kind of human beings with different – (physical) and culture* " [#40.7].

For visual learners, posters or charts may be helpful as these allow learners to connect the various concepts of the lesson together and understand them better. At the workshops a series of posters made by local company was displayed, but these were sold as sets and were very expensive.

The second type, with 5 comments, referred to ***videos / CDs / DVDs***. Examples of comments made are

"*Can we get a video on Sterkfontein caves? Are there any other videos*?" [# 36.8];

"*CD's for evolution*" [#42.8];

"*If you can design videos for us it will be much easier for learners to understand*" [#46.7].

A list of locally available DVDs was provided for teachers at the workshops. In recent years several relevant programmes (e.g. Discovery World, History Channel, and BBC Knowledge).have been aired on our locally accessible television programmes.

The third type, with 3 comments, indicated that teachers needed ***models***. For example

"*Models of ancenstral creatures*" [#41.8].

Since learners may have different learning styles, the use of visual aids like videos, DVDs, and models may facilitate learner's comprehension of new concepts. This is because what learners may not comprehend by hearing, they might grasp by the use of visual aids (Rains, Kelly and Durham, 2008). Mohammad and Kumari (2007) point out that the use of visual aids when teaching difficult topics (like evolution in this case) is important as the resources enrich the content of textbooks, and help maximize learning opportunities for learners. However, Mohammad and Kumari (2007) warn that too much material can serve to confuse the class, so sticking to a few would be best.

The third sub-category in the 'support material for teachers' category, with 9 comments, had comments showing that teachers needed ***assessment material***. Although three did not specify what, six comments mentioned specific assessment material needed.

The first related to ***question papers*** (4 of 12 comments). Examples of comments made are

"*Model question papers*" [#15.7];

"*Examples of questions at grade 12*" [#31.I8];

"*Possible types of questions for Matric Exam*" [#47.7].

Model question papers and answers are useful as they expose learners to the type of questions and answers expected of them during exams. However, as discussed earlier on p.58, when made available, teachers should be critical of them, and should be careful about how they are used.

The second 'assessment material' sub-category had to do with ***rubrics / memos***. Two comments were made. For example

"*Assessment guides and rubrics thereof*" [#39.7].

Four further sub-categories relating to support material for teachers are listed in Table 16, but, because they each contained few comments I have not reported on them.

The second category, with five comments (11% of all the comments), showed that the teachers needed support material for learners, for example ***textbooks*** and ***study guides.*** Mohammad and Kumari (2007) assert that textbooks can serve as a vehicle for delivering content knowledge provided textbook writers have ensured provision of adequate knowledge with no misconceptions, included learning aids such as pictures and activities to challenge learners.

The third category, containing four comments (i.e. 9%), indicated that the teachers needed ***help with improving their knowledge.*** Three of the four comments mentioned need for ***content knowledge***. Teachers commented

> "*More clarification about classification of organisms – at the moment, it's still a bit confusing for me*" [#2.8];
>
> "*Need more core knowledge to boost my background knowledge*" [#5.7];
>
> "*The content was not very adequate for me. I think that more could still be done on content part"* [#17.7].

One of the four comments indicated a need for ***knowledge of religious beliefs***. Four teachers made the following group comment

> "*Overview of all religious beliefs regarding evolution*" [#2, 18, 19, 20.7].

It is interesting to note that when I looked at the teachers' concerns about teaching evolution nearly half of the comments (113 of the 226 comments) indicated that teachers were worried about their inadequate knowledge. When I looked at their needs after the workshop, only four of the 47 comments related to inadequate knowledge. I wondered how accurate their perceptions were about adequacy of their knowledge. Were the teachers overestimating their knowledge? This matter is investigated further in section 4.8.

The fourth category, containing four comments, showed that teachers wanted more workshops. However, the specifics of what should be covered on those workshops were not spelled out. For example

> "*… and also other workshops during next year can also help*" [#27.7];
>
> "*More workshops from the GDE*" [29.7].

4.5.2 Teachers' change of concerns

At the end of the workshop the teachers were asked: *"At the start of the first workshop we asked you what worries or concerns you had about teaching evolution in 2008. Have your concerns changed in any way since then?* This question was asked to get the teachers to think if their concerns had shifted after they got training on the appropriate strategies to use when dealing with controversy, and content-related issues. Twenty-eight teachers from the 2007 and 2008 workshops responded to the question. The responses of both samples were combined for the reason mentioned previously, and in total 30 comments were made. Five main categories and a number of sub-categories relating to changes in teachers' concerns emerged from open coding of responses (see Table 17 on the next page).

The major category to do with change of concerns contained three-quarters of the 30 comments, and related to better understanding. The comments clustered into three sub-categories.

- **Understanding the content:** The most common sub-category, containing 12 comments, related to the teachers ***better understanding the content.*** Teachers made comments such as

  > "*The content is not so unfamiliar anymore. Many concepts made very clear*" [#4.I8];

"*I now understand evolution better than before, because the workshop was well planned concerning the content, the facilitator has explained it, in such a way that, I think no one who attended the workshop has a problem*" [#16.7];

"*I think now I understand evolution from a scientific point of view*" [#21.7];

"*I can be able to explain evolution to learners. And myself I understand the topic than before.* [Before the workshop] *I would be unable to explain evolution to others*" [#27.7];

"*Feel better prepared knowledge wise*" [#36.7];

"*Now I will be able to teach to teach evolution based on scientific knowledge*" [#40.7];

"*I think I have gained a lot now. I can stand and tell them scientifically where we originate from*" [#46.7];

"*I missed that workshop but as of today I have gained a lot of knowledge with regard to evolution and feel that with the resources that we went through today I can be one of the great teachers of evolution* " [#15.7].

The change of concerns reflects the relevance of information provided to the teachers at the workshop (i.e. the workshop paid attention to what teachers needed at that point in time). However, Fuller (1969) and Hall *et al*. (1979) emphasize that information given to teachers to develop them should be repeated across time so teachers are clear of what is required of them.

Table 17: Change of concerns associated with 30 comments from 28 teachers

Workshop	**WS 1 and 2**
Number of teachers who made comments	28
Number of comments listed [average no. per teacher]	30 [1]

Change of concerns about having to teach evolution		**WS 1 and 2**
Better understanding … **21 (70%)**	content	12 (40%)
	how to teach evolution	6 (20%)
	controversial nature of the topic	3 (10%)
Feeling more confident **4 (13%)**	no reason stated	1 (3%)
	reasons stated	3 (10%)
Still feeling excited **1 (3%)**	reason stated	1 (3%)
Yes (concerns have changed) **3 (10%)**	no reasons stated	3 (10%)
Response does not answer the question **1 (3%)**		1 (3%)

Note: Respondents may have more than one comment in a category, so frequencies may not tally to the sample size

- **Understanding approaches to use when teaching evolution:** The second sub-category in the 'better understanding' category related to the ***teachers' certainty about how to approach evolution*** in class (6 comments). For example

  "*Clearer how to tackle it now*" [#2, 18, 19, 20.7] (group answer);

  "*I know I can teach evolution alongside religious backgrounds, I know it is not meant to change anybodies religion*" [#5.7];

  "*Life Sciences is a practical subject. Everything we do it practically to prove it*" [#33.7];

  "*Because I have a strategy on how to teach evolution"* [#41.8].

- **Understanding the controversial nature of the topic:** The third sub-category referred to the teachers' ***better understanding of the controversial nature of the topic***, containing three comments. Two teachers wrote the same comment because they were seated together

"*Because I now know the difference between evolution and religion*" [#29.7] and

"*Because I know the difference between religion and evolution*" [#30.7];

Another teacher said

"*Being a teacher in a Christian school with the executive body being staunch Creationists, made it difficult to know how I can teach this without too much controversy. Although I still feel anxious – I know how to go about teaching this section*" [31.I8].

Hall and Hord (2006) point out that when teachers' needs for more content-related information and appropriate teaching strategies are met, teachers move towards the next level of concerns which are task concerns. However, Hall and Hord (2006) warn that early concerns cannot be resolved over a short space of time, teachers need to be mentored to ensure that their teaching promotes conceptual understanding. There is no indication that the Gauteng Department of Education will provide any such mentoring.

The second category regarding the change of concerns was related to ***feeling more confident*** about teaching evolution (4 of the 30 comments). One comment did not contain a specified reason for feeling more confident. The other three comments referred to presenting evolution with confidence, making the topic more interesting, knowing what is expected of the teacher. The teachers commented

"*I do not have any worries any more. The presentation and the worksheets they gave us was educational. At the end I've gained a lot, feel comfortable and confident to present to my learners*" [#4.7];

"*Feeling more confident now about making the subject more interesting and hands-on*" [#6.7];

"*More confident and now know what is expected*" [#10.7].

Other categories relating to change of concerns are shown in Table 17. However, because the third category had only one comment, the fourth category did not have explanations, and the comment in the last category was not answering the question, I have not reported further on these categories.

4.6 TEACHER'S UNDERSTANDING OF THE CONCEPT OF EVOLUTION

The data analysis about the teachers' concerns showed that only 25 of the 229 comments (i.e. 11%) specified that the teachers were worried about their inadequate knowledge about evolution. To check how accurate the teachers' knowledge estimate was a second research question needed to be answered.

Research question 2: To what extent did teachers who had to teach evolution understand the fundamental evolution concepts they were required to teach?

To establish the teachers' knowledge, data from three questions were analyzed.

- Teachers' perceptions about the adequacy of their content knowledge. The instrument asked the teachers directly how good their detailed understanding was of the fundamental concepts of evolution listed in the National Curriculum Statement for Grade 12 (see Appendix C2).
- To check their content knowledge, the teachers were asked to explain what is meant by evolution in biology (see Appendix C3).
- To further look into the adequacy of their content knowledge, they were given an evolution quiz questionnaire with misconceptions about evolution where they were asked to indicate whether they consider the 18 listed statements to be true or false (see Appendix C4).

The data analysis from the teachers' explanations of biological evolution and the number of misconceptions held by individual teachers were used to judge how accurate the teachers' perceptions of their subject matter knowledge were.

4.6.1 Teachers' perceptions about the adequacy of their content knowledge

Teachers were given the knowledge-estimate activity to assess their knowledge of the fundamental concepts of evolution (see Appendix C2). The question asked "*How good is your detailed understanding of the fundamental concepts of evolution you are required to teach in 2008?*". Using the Likert scale of "excellent", "good", "satisfactory or "poor" 70 teachers rated their knowledge on each of the 16 evolution concepts listed in the National curriculum statement. In each teacher's data set the scale that occurred most often was used as a descriptor of their knowledge level. For example, Teacher #3.I8 was given an overall rating of "satisfactory" as she had rated her knowledge as "satisfactory" for 14 of the 16 topics and one on each of the categories "good" and "poor". In some instances one overall rating could not be found as the data set was bimodal (i.e. there was a tie in some categories). In these cases the responses were classified based on the two scales that occurred most frequently. For example, Teacher #5.I8 was given an overall rating of "good / satisfactory", because "good" and "satisfactory" were each indicated eight times. The results of this question, shown in Table 18, are grouped according to the categories that occurred most often in the data set of the teachers.

Table 18: Summary of teachers' self-assessed content knowledge (n = 70)

Workshop	WS 1	WS 2 (private)	WS 2 (gov.)	Total
Number of teachers	33	17	20	**70**

Teachers' knowledge estimate of the fundamental concepts of evolution	WS 1	WS 2 (private)	WS 2 (gov.)	Whole sample
Excellent	3 (9%)	0 (0%)	0 (0%)	**3 (4%)**
excellent / satisfactory	0 (0%)	1 (6%)	0 (0%)	1 (1%)
Good	11 (33%)	4 (24%)	3 (15%)	**18 (26%)**
good / satisfactory	2 (6%)	1 (6%)	2 (10%)	5 (7%)
Satisfactory	8 (24%)	7 (41%)	7 (35%)	**22 (31%)**
satisfactory / poor	1 (3%)	1 (6%)	0 (0%)	2 (3%)
Poor	8 (24%)	3 (18%)	8 (40%)	**19 (27%)**

Based on the teachers' own ratings of the concepts they were required to teach, only three teachers were categorized as "excellent", all from the 2007 group. Eighteen of the teachers (26%) were

categorized as "good", based on their ratings of the knowledge of the 16 topics. It is interesting to note that in the 2007 group 33% of the teachers from the GDE schools were categorized as "good", compared to 15% teachers from GDE schools in 2008. Almost a third of the teachers (22 of 70), based on their own ratings of the 16 evolution concepts listed in the national curriculum statement, were categorized as "satisfactory". Just above a quarter of the teachers (19) were categorized as "poor" based on their own ratings. A year before the topic of evolution was implemented (2007), 24% teachers from the GDE schools rated their own knowledge of the concepts they were required to teach as poor, and the year of evolution had to be taught for the first time (2008) 40% of the teachers from the GDE schools were still not confident about their subject matter and rated their own knowledge poor.

4.6.2 Teachers' explanation of biological evolution

I wondered whether the teachers who rated their knowledge highly were as knowledgeable as they felt they were, I conducted an additional analysis to determine if the teachers' self-ratings were accurate, using two different activities. The first instrument required them to explain evolution. Eighty-six teachers responded to the question "*Explain what is meant by evolution in biology".* When analyzing the teachers' responses I realized most of the teachers seem to have provided a definition rather than an explanation, probably because the question did not specifically ask the teachers to explain the mechanisms of evolution. An explanation would have included an explanation of how evolution happens. Initially I had planned to use the criteria below to evaluate teachers' answers. The criteria were developed after I had extracted definitions from six biology dictionaries and asked an "evolution expert" to comment on accuracy (see Appendix F). I then extracted seven points which defined and explained evolution and asked three university lecturers to face-validate the list. Based on the resources reviewed, and the views of the experts consulted, the following seven aspects should be included in an explanation to be considered scientifically acceptable explanation of evolution.

- It is the changes in the frequency of traits in a population over successive generations, so that more favourable traits become more established in the population.
- This happens because individuals in a population exhibit different traits, some of which are advantageous to the individual.
- Individuals better adapted for survival are reproductively more successful (produce more offspring).
- Reproductively successful individuals pass their traits (involving the favourable traits) on to a greater number of individuals in the next generation.
- In this way favourable traits become more frequent in the population over successive generations and the population evolves (NB. Individuals don't evolve).
- Only genetically-based traits can be passed to future generations.
- The scale of the change may be small or large:

  Microevolution: small-scale changes (below species level) in the frequencies of alleles in a population, over successive generations.

Macroevolution: large-scale changes (at or above species level). Genetic changes in a population can result in the development of a new species if individuals become reproductively isolated (i.e. can no longer have fertile offspring with individuals from the original species).

As the teachers had not specifically been asked to explain the mechanisms of evolution, it was decided that the following three criteria would be accepted as a correct answer, because they would provide an adequate **definition** of evolution, in spite of not including the mechanisms.

i) populations evolve (not individual organisms),

ii) evolution involves changes in genetic traits which promote survival,

iii) evolution occurs over several generations.

A correct explanation had to include all three criteria and be clearly worded (i.e. the wording should make sense and should include no errors).

Moran (1993) asserts that the general public, including science teachers, seems to be confused about the accurate meaning of biological evolution. He goes on to say the confusion exists because even biologists do not agree on the precise meaning of biological evolution. However, in this study the three aspects mentioned were used because when one looks at relevant sources the three aspects are repeated, for example Moran (1993); National Academy of Science and Institute of Medicine (2008); and various tertiary level textbooks.

Most answer were poorly worded, perhaps because some of the teachers (n = 42) were second language speakers and could not express themselves well in English. In addition, the teachers' inadequate knowledge about evolution affected their wording. When analyzing the teachers' explanations four main categories were used: "correct", "has the general idea", "unsatisfactory" and "has no idea". Each category is explained in Table 19.

Table 19: Accuracy of the teachers' biological explanations of evolution (n = 86)

Workshop	**WS 1**	**WS 2 (private)**	**WS 2 (gov.)**
Number of teachers	28	21	37

Teachers' biological explanations of evolution		**WS 1**	**WS 2 (private)**	**WS 2 (gov.)**
Correct (well worded / no errors) … **(n = 1)**	and complete (mentions all three criteria)	0	1	0
	but incomplete (omits up to two criteria)	0	0	0
Has the general idea (alludes to at least two criteria) but … **(n = 2)**	… is poorly worded	1	0	0
	… has one error	1	0	0
	is incomplete	2	0	0
Unsatisfactory (has a vague idea, alluding to only one criterion) and … **(n = 56)**	is poorly worded	6	7	13
	has one error	2	5	5
	has two errors	5	7	8
	has three errors	5	6	11
	has four errors	0	0	1
	is incomplete	13	20	25
Has no idea (n = 27)	off-track (does not mention of any of the 3 criteria)	8	0	11
	incoherent (wording makes no sense)	11	0	9

Note: An answer may contain more than one of the problems in a category, so frequencies may not tally to the sample size

It was disappointing to find that only one teacher of the 86 teachers who provided explanations had a **correct explanation** of biological evolution. In the explanation all the three features were present and no misconceptions were detected. The teacher commented

> "*Mutations occur. This results in variations between individuals of a species. For some the change is unfavourable, while for others their variation is an advantage. For those who are advantaged, they are able to reproduce more than the others are. Their numbers and contribution to the gene pool increases, while for the former group, their contribution decreases. Result - changed population, which might, eventually, become a new species. If environment changes (or) organisms move to new environment, then this is especially true"* [#9.I8].

A further two teachers of the total sample were judged to have **a general idea**. The teachers were judged this way because they alluded to at least two out of the three aspects necessary to explain biological evolution but had other problems. Although one of the two definitions was well worded, it was incomplete because the teacher did not mention that populations evolve. Instead an error detected in the definition implied that individual organisms evolve not populations. The first teacher said

> "*Evolution is genetic changes that happen over time and allow and (sic) organisms to be better adapted to its environment (genetic change/mutations) is generally fatal or harmful but can sometimes be to and (sic) organisms benefit. Organisms do not evolve to adapt to their environments it is spontaneous*" [#10.7].

The second definition in the "general idea" category was poorly worded, although it held no errors i.e. I had some idea what the teacher was trying to say, but it was poorly explained and the criterion that evolution occurs over successive generations was missing. The teacher explained as follows:

> "*Life originated from a common ancestor or group of organisms. Mutation events that were advantageous to organisms allowed those genes to be fixed so diversity occurred. This lead to different phyla etc emerging & later different classes etc*" [#45.7].

Ball and Feiman-Nemser (1988) point out that having a solid grasp of content knowledge and understanding of central concepts relating to specific topics (like evolution in this case) is important so teachers become effective and help their pupils to learn. Teachers with only a general idea of the concept of biological evolution need help in clear ways of putting ideas across to learners, to promote conceptual learning.

More than half of the explanations (i.e. 56 of the 86) of the concept 'biological evolution' seemed ***unsatisfactory***. Unsatisfactory explanations were judged thus because they were incomplete, or contained errors, or were poorly worded. The misconceptions identified in the explanations are reported at the end of this section.

- **Incomplete:** Two definitions in the category ***unsatisfactory*** were categorized as ***incomplete***. The definitions both alluded to only one criterion, although the wording was adequate and no misconceptions were identified.

  "*Change over time. Survival of fittest*" [#33.I8];

- **Incomplete with errors:** Of the 56 definitions 30 were ***incomplete*** (alluded to one criterion) ***with errors***. In the following example, errors identified in the explanation involve organisms changing (individual organisms do not evolve, only populations evolve), individuals adapting to changing environments, only the best adapted individuals will reproduce (this is not necessarily the case, as

even less adapted individuals reproduce but reproduce fewer offspring compared to better adapted individuals) and evolution occurring so that the organism carries out its functions to the best of its ability (which is not correct).

> "*Evolution is the adaptation (permanent) of a living organism to a changing environment to ensure survival of that living organism. It allows the organism to carry out its functions to the best of its ability. It ensures that only the "fittest" or best-adapted individuals will reproduce to result in stronger organisms surviving*" [#6.8].

- **Poorly worded:** definitions were categorized as poorly worded when the reader at least had some idea what the teacher was trying to say, but the explanation was not well explained and thus incomplete or misleading. From the analysis of the explanations 18 of the 56 definitions were ***poorly worded***. For example

> "*Evolution means change and adaptation to the environment over time, therefore how species have adapted to suit their environment better*" [#3.I8].

When the teachers were assessing their knowledge of the 16 fundamental concepts of evolution listed in the National curriculum statement, 19 of the 70 teachers (27%) rated their knowledge as "poor", The explanations provided suggested that a substantially larger number of teachers had limited understanding of evolution, containing many misconceptions. Twenty-seven of the 86 teachers, based on their definitions, were judged to have **no idea** of what evolution is. A year before the topic of evolution was due to be taught i.e. at the stage of preparing to teach it, 13 of the 28 teachers (46%) from the 2007 group had no idea of what biological evolution was. During the implementation year 14 of the 37 teachers (38%) from the 2008 group had no idea of the concept of biological evolution. Their definitions were either ***incoherent*** or ***off track***, or both ***incoherent and off track***. It is interesting to note that during the workshop run the year of implementation no teacher from the private schools fell into the category ***have no idea***.

- **Incoherent:** Of the 27 definitions eight were simply a collection of jargon words, which is often a sign of confusion. For example

> "*How things change to adapt to their environment and only natural selection will survive*" [#34.8].

The underlined portion of the definition does not make sense and renders the definition incoherent.

- **Off track:** Seven definitions in the category ***no idea*** were classified as ***off track***, because they contained serious misconceptions linking to some other concept which had nothing at all in common with the correct biological definition of evolution. For example

> "*Evolution means change e.g. like in metamorphosis. However the change in structure and function creation of something new but still related to the past one e.g. characteristics, survival strategies etc. It is change normally for the better, it overcomes the problems of the old order*" [#5.7].

In biology metamorphosis means "*an abrupt transformation from one anatomically distinct stage (juvenile) to another (adult)*" (Kardong, 2006, 745). The major anatomical changes occur in the

life cycle of an organism, for example, the transformation of a tadpole to a frog. This concept has nothing at all in common with the correct biological explanation of evolution, hence the explanation was considered off track. The definition reveals that the teacher was confused and did not understand evolution because evolution does not mean abrupt change of form in a life cycle of an organism. Rather changes in gene frequencies in populations account for evolution of species (Clores and Limjap, 2006).

- **Incoherent and off track:** Twelve of the 27 definitions provided seemed to be both ***incoherent and off track***. This is because the definitions did not make any sense and had nothing at all in common with the correct biological definition of evolution. For example

  "*That creation of everything on earth is from God – even if they are different. God created biotic and abiotic in interrelationship way – one another developed by others. The miracles do happened*" [#26.7];

  The explanation is off track because it provides a religious explanation for biodiversity rather than a scientific one. It is off track because it does not explain the change process in terms of biological reasons. The second sentence in the definition is incoherent as it does make sense.

4.7 TEACHERS' MISCONCEPTIONS ABOUT EVOLUTION

Nadelson (2009) says unless teachers are subjected to situations that require them to show their understanding of the concept of evolution, it may be difficult to identify commonly held misconceptions. Two sources of information allowed me to identify teachers' misconceptions. The first was the teachers' definitions of evolution. The second one was the evolution quiz.

4.7.1 Misconceptions contained in the definitions

The definitions provided by the teachers in this study included numerous misconceptions, as outlined in Table 20. The two which show the most fundamental misunderstanding of evolution are also the most frequent emerging in the definitions of almost half of the teachers. Others were less frequent in the definitions, and their extent only emerged in the evolution quiz. These are discussed in section 4.7.2.

Table 20: Thirteen errors incorporated in the definitions of biological evolution of 86 teachers

Misconceptions	Frequency
Organisms evolve so as to adapt to environmental changes or food needs	39 (45%)
Individuals or organisms change	39 (45%)
Organisms mutate or evolve in order to survive	14 (16%)
Evolution means change of a species	11 (13%)
Evolution explains origin of life	9 (10%)
Evolution means that gradual changes are carried over genetically (reproduction not evolution)	9 (10%)
Evolution is creation or evolution of only animals	7 (8%)
Evolution is when organisms change from one form to another	5 (6%)
Evolution means moving of organisms on to some end point (from simple to complex organisms)	4 (5%)
Evolution is changes due to time	3 (3%)
Evolution explains the creation of Earth	2 (2%)
Only the fittest will reproduce	2 (2%)
Only animals evolve	1 (1%)

4.7.2 Misconceptions identified from the quiz

The results from the "evolution quiz" were used to identify whether teachers held misconceptions, and the number of misconceptions held by teachers was then used as measurement of their subject matter knowledge about evolution. Eighty-eight teachers responded to 18 erroneous statements in the quiz. Six statements had to do with evolution / religion controversy and did not indicate problems with teachers' knowledge of biological evolution, so were excluded from the reporting of the data. The remaining 12 misconceptions dealt with subject matter knowledge, and were analyzed. However, one of the 12 misconceptions (i.e. evolution results in increase in variation within organisms) was excluded in reporting the data, because the wording of the item was problematic. People tend to focus on the first part of the statement 'evolution results in increase in variation' and miss the second part 'within organisms' which is what renders the statement incorrect. Evolution does not occur within organisms. Their genotype is fixed and cannot change.

The misconceptions identified, and their frequency, are reported in Figure 7, and are ranked according to the frequencies of responses of the first group of teachers (from 2007).

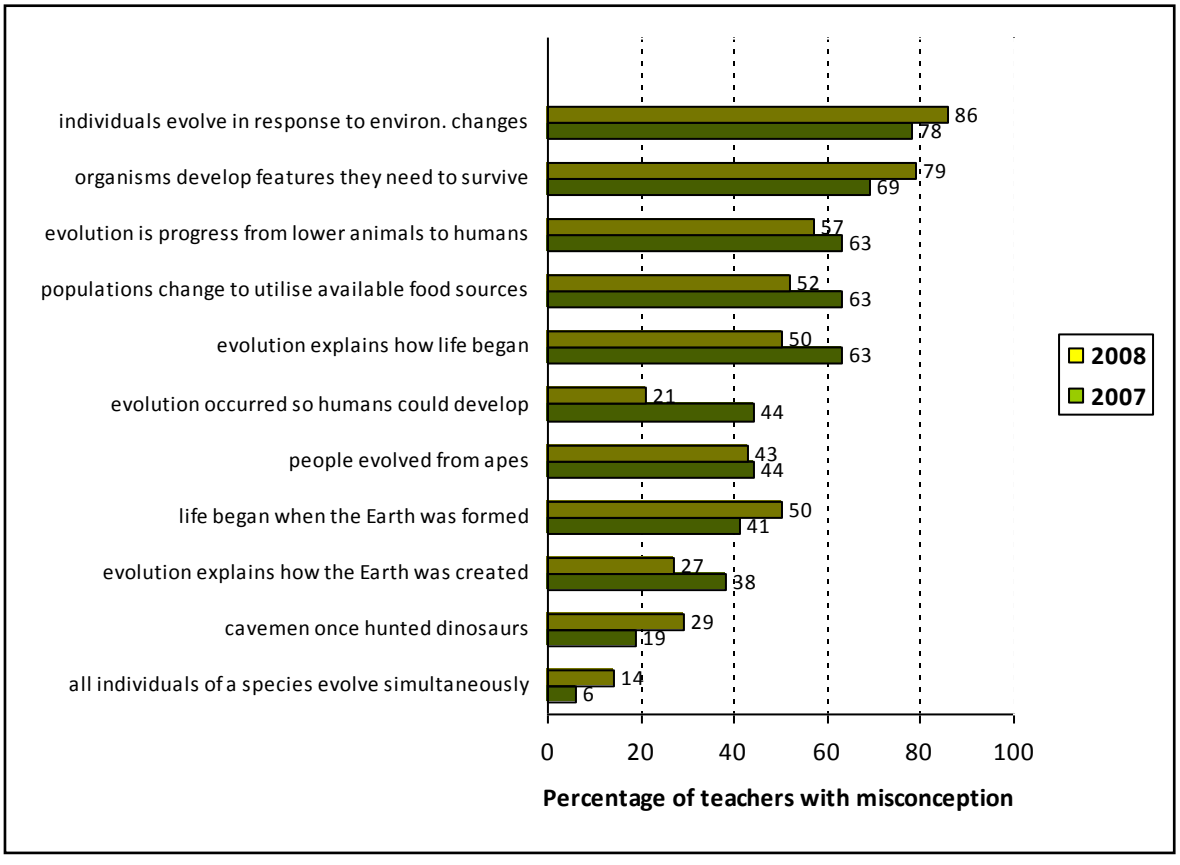


Figure 7: The frequency of misconceptions in the 2007 and 2008 groups of teachers

However, as shown in Figure 7 there were a lot of similarities between the 2007 and 2008 groups of teachers, in terms of their rankings. Though similarities were the general rule, there were exceptions: for example, 44% teachers in the 2007 group held the misconception that evolution occurred so that

humans could develop, compared to only 21% teachers in the 2008 group. Seventeen of the 56 teachers (30%) from the 2008 group came from the private schools, and only two of the 17 held the misconception.

Figure 7 shows that a high proportion of the teachers held certain misconceptions. Five of the misconceptions were held by more than 50% of the teachers in the 2007 and 2008 groups.

- **Individual organisms evolve in response to environmental changes:** This most frequent misconception was held by 86% teachers from the 2008 group and 78% teachers from the 2007 group.

  There are two errors in this statement. Firstly, individual organisms cannot change as they retain the same genes throughout their lifetime (Freeman and Herron, 2004). It is only populations, not individual organisms, which can evolve. It is possible that when teachers were responding to the "evolution quiz" questionnaire they could not focus on the subtle terms that were important in the text, for example "individuals" and "organisms". The teachers may have missed those terms which made the statement incorrect, and that may be one of the reasons they had so many misconceptions. Secondly, the variation in the alleles occurs by chance and not in response to environmental changes. These variations already exist in individuals. It is chance mutations or genetic variation, where individuals happen to have developed traits which give them a greater chance of survival, which make an organism reproductively more successful, allowing individual to pass the traits on to successive generations. Ultimately the favourable traits spread through the population, and the population evolves. Nadelson (2009) points out that the role of chance events in the process of evolution seems not well understood. Freeman and Herron (2004) point out it is the mutations and genetic recombinants that occur by chance. Natural selection acts on variants with survival traits so as to increase adaptation to the environment (i.e. natural selection is a non-random act).

- **Evolution occurs when organisms develop features they need to survive:** This was the second most frequent misconception. Usually this false idea is related to the notion of need, that is, people incorrectly believe that organisms develop new features because they need them to survive (Tindon and Lewontin, 2004). The statement is disputed by biologists, as the misconception contains Lamarkian ideas (Jimenez Aleixandre, 1994). In this study many teachers, 79% in the 2008 group and 69% in the 2007 group, held the misconception. Numerous studies have shown that the misconception is very pervasive and may even persist after advanced courses for evolution. However, in an American study by Rutledge and Warden (2000), who identified this misconception in a sample of 552 American biology teachers (evolution is "*the development of characteristics by organisms in response to need*"), the misconception was far less pervasive than in my study – held by only 10.7% of the 552 teachers in their study.

- As mentioned in the previous bullet, biologists recognize the development of new traits is a result of two processes "*random changes in genetic material (random mutations or sexual recombination) then survive or disappear due to ... natural selection*" (Bishop and Anderson, 1990, 420). The genetic variation precedes environmental changes and is independent of

environmental conditions. However the general public (including teachers) fails to recognize that the development of new traits in a population occurs as a result of random changes in genetic material and non-random selection by natural factors, believing instead that environment influences development of new features organisms "need" to survive. Such misinterpretation by teachers needs to be corrected, and the fact that organisms cannot change at will as their genotype is fixed has to be continually emphasized by facilitators during in-service workshops.

- **Evolution "betters" organisms and increases their complexity, resulting in a steady progress upward from lower animals to humans:** This was the third most common misconception (held by 63% teachers in the 2007 group and 57% teachers in the 2008 group). Rutledge and Warden (2000) report that 14.5% of the 552 teachers in their American study selected evolution is a "*change of simple to complex organisms*" as the phrase that best described the process of evolution, which is lower than the percentage in my study. This misconception conveys the message that evolution proceeds in a specific direction leading to the improvement of organisms, like climbing a ladder, with humans at the top (The University of California Museum of Paleontology, Berkeley, 2006), implying that organisms are always getting better. Evolution makes organisms better "*only in the sense of increasing their adaptation to the environment*" (Freeman and Herron, 2004, 91). The whole idea behind evolution is survival in which those organisms with the most beneficial traits from their genes in their environment are best adapted for survival (The University of California Museum of Paleontology, Berkeley, 2006). Although evolution has resulted in complex organisms, at the same time simple organisms such as bacteria, fungi and yeast thrive and do not become more "advanced" (Campbell *et al*., 2008; and McCarthy and Rubidge, 2005). And sometimes evolution results in organisms becoming simpler. For example, earlier birds in the fossil record (e.g. *Archaeopteryx* which had teeth), evolved to be simpler (Freeman and Herron, 2004). If organisms were marching up a ladder of progress, all the "simple" organisms would die out.

- **Evolution is when physical features in a population change to suit a food source:** The fourth most common misconception was held by 63% of the teachers in the 2007 group and 52% of the teachers in the 2008 group. Available food sources in a particular environment do not influence evolutionary changes, for the same reasons already explained for environmental changes.

- **Evolution explains how life began:** Sixty-three percent teachers in the 2007 group and 50% teachers in the 2008 group had the idea that evolution is a theory about the origin of life. This is because the general public is under the impression that biological evolution explains the origin of life (Rice, Warner, Kelly, Clough and Colbert, 2010). Rice *et al*. (2010, 141) explain that "*the theory of evolution, both currently and as first conceived by Darwin and Wallace, neither provides, nor requires, an explanation for the origin of life*". That is, evolution by natural selection focuses on how life on Earth changed after it began, and the mechanisms responsible for change following the origin of life.

Figure 7 shows that six of the misconceptions were held by less than 50% of teachers in the 2007 and 2008 groups.

- **Evolution has taken place in order for humans to develop:** The sixth most common misconception was held by 44% of the teachers in the 2007 group but only 21% of the teachers in the 2008 group. As explained previously, evolution neither has some targeted end point, nor is it about a gradual development towards humans.

- **Evolution explains that people evolved from apes, chimpanzees or monkeys:** This false assumption comes from the never-ending controversy around human evolution. Scott (2009) states that this misconception is commonly held by creationists and is disseminated by them and spread by their media. In this study 44% teachers in the 2007 group and nearly the same percentage of teachers (i.e. 43%) in the 2008 group had this false idea. Scientists do not make such claims: they explain that humans and the various primate groups have similar characteristics that their common ancestor would have had (e.g. have fewer offspring, binocular vision, opposable thumbs, bear finger tips and flat nails instead of claws, etc.) which is an evidence that they share a common ancestor (Scott, 2009; Campbell *et al*., 2008; and Raven *et al*., 2005). The similarities among the various primate groups help scientists to classify organisms taxonomically (e.g. humans and apes are categorized under the order of primates). Scientists agree that the common ancestor humans share with apes diverged into separate lineages, one eventually becoming humans (Campbell *et al*., 2008; and Raven *et al*., 2005).

- **Life began when the Earth was formed:** Fifty percent of the teachers in the 2008 group and 41% of the teachers in the 2007 group believed this statement to be true. This is scientifically incorrect, because scientists think that the earliest forms of life appeared 3.4 billion years ago and the Earth was formed 4.6 billion years ago (McCarthy and Rubidge, 2005). The earliest evidence for life comes from fossilized cyanobacteria called stromatolites that are estimated to be about 3.4 billion years old (Campbell *et al*., 2008). Holding on to the idea that life began when the Earth was formed ignores the millions of years that passed after the Earth was created and before life originated, and may be a consequence of the religious creation story where the formation of Earth and the appearance of life happened in the same week.

- **Evolution explains how Earth was created:** While it is widely accepted that evolution explains how life diversified after it was created, some people think that evolution explains the creation of Earth (i.e. 38% teachers in the 2007 group compared to 27% teachers in the 2008 group)**.** This is scientifically incorrect as the theory of evolution by natural selection does not seek to explain how Earth was created, but helps us to understand mechanisms behind the biodiversity on Earth.

- **Ancient humans (cavemen) once hunted dinosaurs:** About one in four teachers held this misconception (29% in the 2008 group and 19% in the 2007 group). This reveals that the teachers lacked an understanding of the geological time line. The study of fossils shows that dinosaurs first appeared 300 million years ago and went extinct 65 million years ago, which was long before humans evolved (Campbell *et al*., 2008; McCarthy and Rubidge, 2005; and Raven *et al*., 2005).

- **All individuals of a species evolve simultaneously:** Fourteen percent of the teachers in the 2008 group and six percent of the teachers in the 2007 held this misconception, roughly one in ten teachers only. Evolution by natural selection is a gradual process that occurs over time. It results in populations evolving. Not all individuals will evolve at the same time.

4.7.3 The extent of misconceptions held by each teacher

In an attempt to generalise the extent of misconceptions held by the teachers in this study, five categories were developed using data from the evolution quiz questionnaire. The number of misconceptions held by individual teachers were categorized as "few" if the teacher only had one or two misconceptions out of 11 , "several" for three to four misconceptions, "numerous" if the teachers had five to six misconceptions, and "extensive" for more than eight misconceptions (see Table 21).

The names of these categories were looked into by two members of staff. They looked at the meaning of the relative terms, and (independently) tried to match them to percentage frequencies and then calculated back to frequencies.

Table 21: Extent of teachers' misconceptions (n = 86)

Extent of Misconceptions			Frequency of teachers per category	
Category	**% of statements incorrect**	**no. of statements incorrect (out of 12)**	**Number**	**Percentage**
None	0	0	2	2%
Few	1-16%	1-2	11	13%
Several	17-33%	3-4	17	19%
Numerous	34-65%	5-7	34	39%
Extensive	≥ 66%	≥ 8	24	27%

Just above one quarter of the group (i.e. 27% teachers in the 2007 and 2008 groups) had *extensive misconceptions* about evolution. The largest proportion of the teachers (39%) had *numerous misconceptions*. The range in this category was from a third to two thirds of their answers being incorrect, that is one or two of every three statements checked were answered incorrectly. Nineteen percent of the group had *several misconceptions*. Only thirteen percent of the teachers had *few misconceptions*. Only two of the 86 teachers did not have any misconceptions. Unless these teachers are helped, teachers would not have an understanding that many of these ideas they have are incompatible with scientific theory. As a result, learners are going to be taught incorrect information.

Bishop and Anderson (1990) point out that for teachers to change students' erroneous ideas about evolution, they themselves must understand the misconceptions and their sources. Therefore it is necessary that in-service training planned for teachers should identify teachers' misconceptions of the evolutionary process and mechanisms and correct them by providing teachers with relevant information and appropriate strategies to use in class when dealing with misconceptions held by learners. I wondered if the teachers' self-rated readiness to teach the content (see section 4.8) was accurate.

4.8 THE ACCURACY OF TEACHERS' PERCEPTIONS ABOUT THE ADEQUACY OF THEIR CONTENT KNOWLEDGE

The lack of understanding of the theory of evolution displayed by the teachers' definitions of biological evolution and the results from the evolution quiz, are a source of concern for the researcher. How accurate are teachers' perceptions about the adequacy of their content knowledge? I compared each teacher's self-assessed knowledge and the extent of misconceptions each teacher had, to decide how accurate their estimate of their knowledge was. From the 2007 and 2008 groups, only 56 teachers completed both activities that I used to base my judgement on (the evolution quiz and the knowledge-estimate activity). The process is summarized in Figure 8, which shows how the categories already developed and reported by the researcher earlier in the chapter were used to match each teacher's self-rated knowledge to the frequency of the misconceptions held, in order to judge the accuracy of their knowledge estimates.

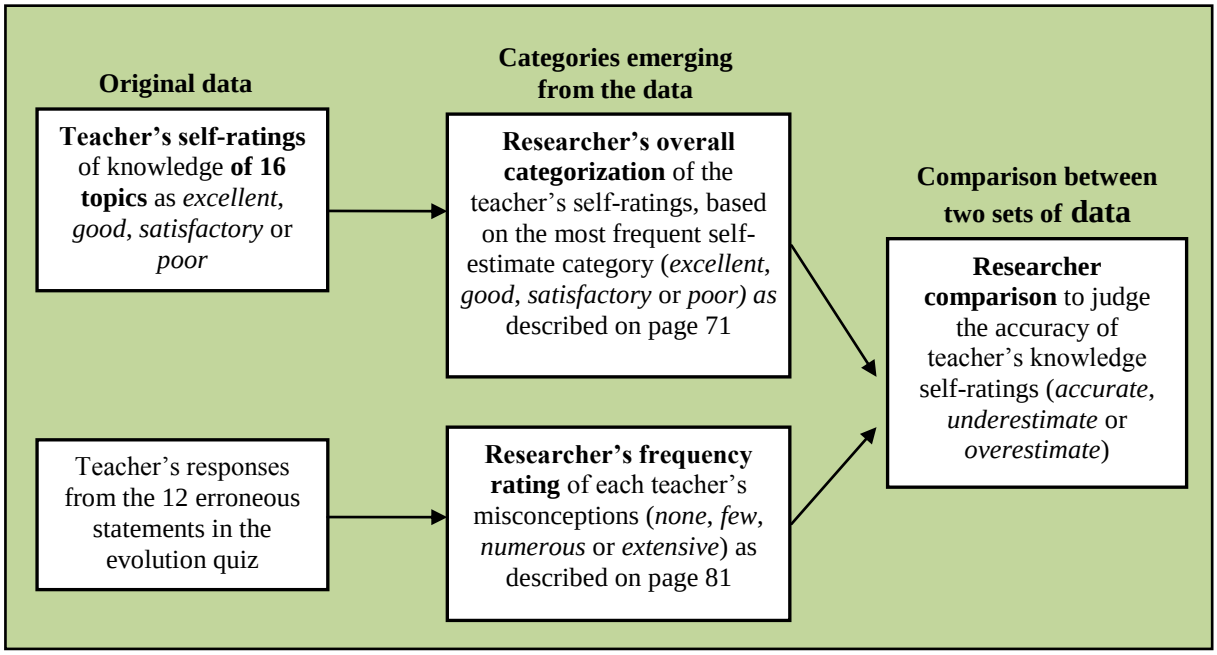


Figure 8: Summary of steps taken to develop three categories used to judge teachers' self-rated knowledge

- The teacher's perception was judged to be "accurate" if the teacher's self-rated knowledge was categorized as *poor* and the number of misconceptions held by that individual were *several* (i.e. three or four), *numerous* (i.e. five or seven) or *extensive* (i.e. eight or more), or if the knowledge category was *good* or *satisfactory* and there were *few* misconceptions.

For a teachers' perception about adequacy of their knowledge to be judged as "under-estimated" or as "overestimated" there needed to be a mismatch between the number of misconceptions held by the teacher and the category the teacher's knowledge fell in, based on the teacher's own rating.

- For their knowledge estimate to be judged "underestimated" a teacher's self-rated knowledge had to be lower than the level of misconceptions held by that teacher. Knowledge was judged as "underestimated" when the knowledge category was *poor* yet the teacher had *few* or *no*

misconceptions, or when the knowledge category was *satisfactory* / *good* and there were *no* misconceptions.

- Teachers were considered to have "overestimated" their knowledge if they said their knowledge was *excellent* or *satisfactory* but had *several* misconceptions. The mismatch was judged to be a "serious overestimate" when the gap was larger than this. Examples include when the knowledge category was *good* or *satisfactory* yet misconceptions were *numerous* or *extensive*.

Similar judgements were made when there were mixed knowledge categories. A summary of results is provided in Table 22.

Table 22: Accuracy of teachers' perceptions about adequacy of their content knowledge (n = 56)

Category	Frequency	%
Accurate	17	30%
Under-estimate	3	5%
Over-estimate	36 (27 of them seriously)	64%

Just under a third of the teachers (30%) had estimated their knowledge fairly **accurately**. This implies that these 17 teachers were aware about how adequate or inadequate their content knowledge was. For example, Teacher #43.7 had a self-rated knowledge estimate categorized as *poor* and held *numerous* misconceptions, indicating an accurate estimation. Three teachers (5% of the sample) had **underestimated** their knowledge. For example, Teacher #19.I8, based on her own perceived knowledge of the 16 fundamental concepts of evolution they were required to teach, was categorized as having *poor* knowledge, but the teacher had only one misconception, which suggests she may have underestimated her knowledge. Almost three out of every five teachers (i.e. 64%) had **over-estimated** their knowledge. As an example, the self-rated knowledge of Teacher #19.7 was categorized as *satisfactory*, but the teacher held *several* misconceptions (i.e. four). Twenty-seven of the teachers seriously overestimated their knowledge of the concepts of evolution. For example, the knowledge estimate of Teacher #10.8 was categorized as *good* (based on her self-ratings) but she had *extensive* misconceptions (i.e. nine).

Shulman (1986) says that it is crucial that teachers understand the content they must teach as it helps them to teach in a way that leads to conceptual understanding. Shulman adds that without understanding of specific topics (like evolution in our case) many teachers seem to be unaware of the common misconceptions involved in specific topics that they should deal with when they teach. Shulman (1986) identifies knowledge of commonly held misconceptions as a vital component of teachers' pedagogical content knowledge, which is essential for effective teaching. Teachers need to know when they are overconfident about their adequacy of their content knowledge, and if they have misconceptions, so they do something about it. If they are unaware that they have misconceptions, the misconceptions could be passed on to the learners.

4.9 CONCLUDING REMARKS

Having conducted concerns and needs analyses it was possible to identify a variety of concerns of the *Life Sciences* teachers in this study about the teaching of evolution. Furthermore, many teachers had

deficient content knowledge, and while many were aware of it, a large proportion was not. So whilst many teachers did not identify their lack of knowledge of evolution as a concern, the researcher showed that it was a source of worry, and a deficiency which needs to be addressed. This is an important finding for those responsible for professional development.

These results are used in Chapter 5 to draw conclusions and to make recommendations.