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

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CHAPTER 3

Research methods and design

3.1 OVERVIEW OF CHAPTER

This study investigated the concerns and needs of South African *Life Sciences* teachers having to teach evolution for the first time to Grade 12s in 2008. A description of what was done to answer the research questions which guided the study is provided in this chapter. The research questions used in this study are listed in Chapter 1, section 1.8, but are repeated in this chapter for the convenience of the reader.

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

The second research question, which might seem unrelated, was to focus my attention on one of the needs, which was to find out whether *Life Sciences* needed help on content knowledge.

The chapter also gives a rationale for why specific research methods were chosen, and explains how the results were analyzed.

3.2 RESEARCH DESIGN

It is essential to define the word *research* before looking into research design, as the word *research* is popularly used in many contexts, and needs to be understood. According to Kerlinger (1986, 10) research is a *"systematic, controlled, empirical, and critical investigation of natural phenomena guided by theory and hypotheses about presumed relations among such phenomena".* Being guided by theory (i.e. interrelated set of constructs used with the purpose of explaining and predicting an observed phenomenon) enables researchers to successfully use these constructs to explain, and to some extent predict, phenomena under investigation (Kerlinger, 1986). That is why my study is guided by a theoretical framework, as discussed in Chapter 2.

LeCompte and Schensul (1999) point out that every systematic process undertaken to uncover the truth or to answer a question requires a plan of action. In research the plan of action for discovering the truth is called a research design (Leedy, 1989). LeCompte and Schensul (1999, 62) refer to research design as a *"blueprint for action"* used to guide one's research. A blueprint for action includes details of what approaches and instruments will be used, how sampling will be done, and how the data will be analyzed. A planned research design assists researchers to make better informed decisions on their choice of approaches to use to collect, analyze and interpret data in an attempt to answer research questions. Figure 3, on the next page, provides an overview of the research design for this study.

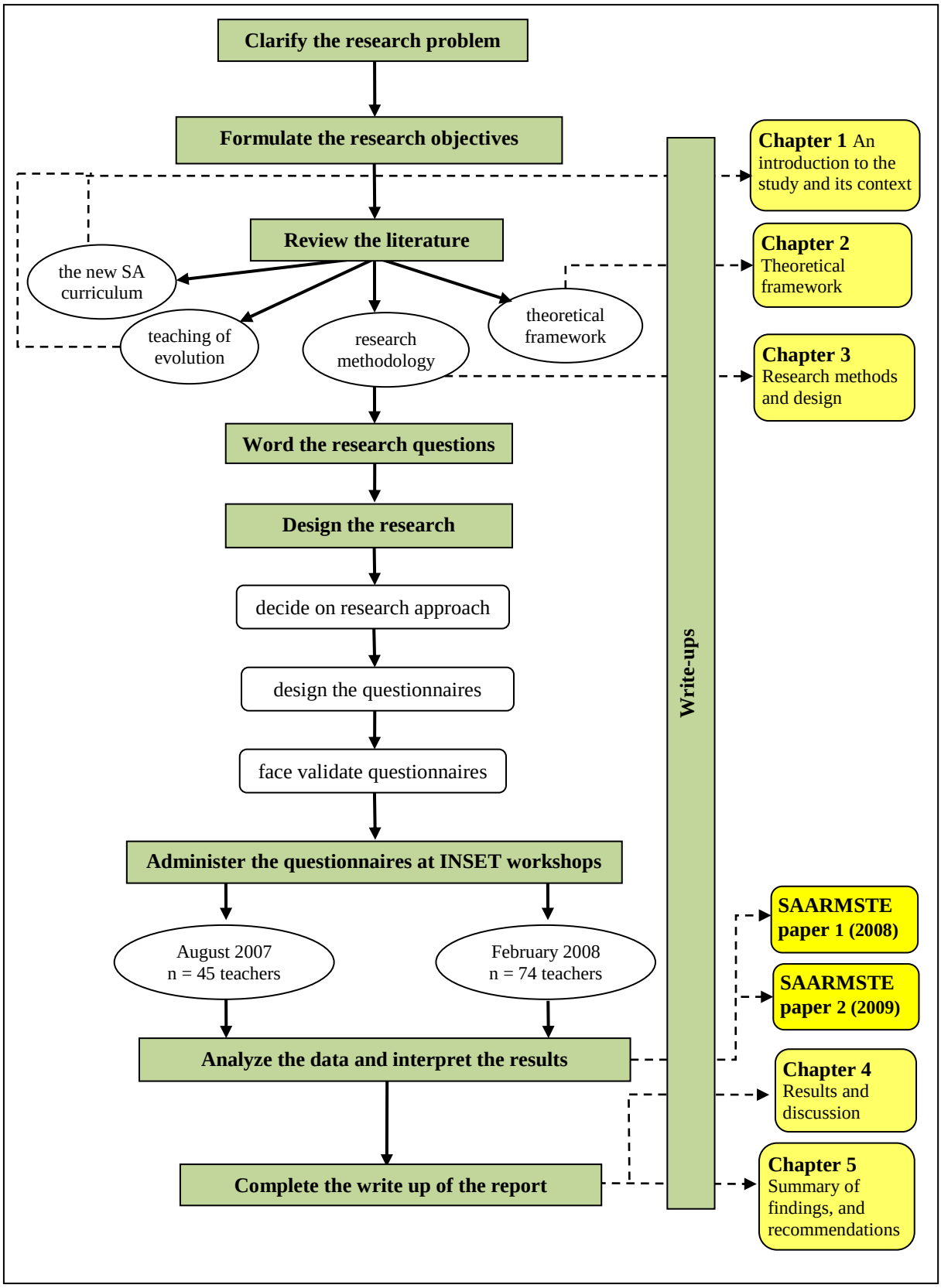


Figure 3: Flow chart showing the overall research design of the study

3.2.1 Research paradigm

A paradigm provides a conceptual framework for seeing and making sense of the social world (LeCompte and Schensul, 1999). According to Guba and Lincoln (1994) paradigms are worldviews or belief systems held by researchers regarding how the truth is discovered. They are an important *"theoretical construct for illuminating fundamental assumptions about the nature of reality"* (Patton, 2002, 72). Patton (1982) and LeCompte and Schensul (1999) contend that within a research process the beliefs researchers hold will reflect in the way in which researchers design their research, collect data, analyze data and present their results. Therefore, it is important that researchers recognize their paradigm, as different paradigms are based on differing assumptions that shape the research design and influence the role of the researcher in the research process.

Three common research paradigms are discussed here: the positivist research paradigm (often called the quantitative paradigm), the constructivist research paradigm (often called the qualitative paradigm), and the eclectic – mixed methods – pragmatic paradigm (Reeves and Hedberg, 2003), also referred to as the paradigm of choices (Patton, 1980) and mistakenly called the mixed-methods paradigm. The paradigms are often misleadingly named after the methods used by the researchers (i.e. quantitative, qualitative and mixed-methods paradigms) rather than after the underlying belief systems. The first two research paradigms are discussed because they were historically dominant, and the third because it is relevant to my study.

The positivist paradigm became popular in the 1960s and was used in the social sciences to guide educational and psychology research (Patton, 2002). According to LeCompte and Schensul (1999, 42) the basic belief guiding positivists is that there is single reality out there which is *"observable and understandable".* That is, there is an objective reality that may be conceptualized and which is not socially constructed (Mertens, 2005). LeCompte and Schensul (1999) and Mertens (2005) point out that researchers located in a positivist paradigm base their way of looking at things on an empiricist philosophy. That is, positivists believe that the social world can be isolated and be studied in the same way "*that physical scientists treat physical phenomena"* (Johnson and Onwuegbuzie 2004, 14). The fundamental assumption of this philosophy is that a scientific method is the best method to uncover the processes by which both physical and human events occur (Mertens, 2005). However, operating like natural scientists in a social world separates positivists from the world of study and channels researchers to stick to what they can observe and measure (Johnson and Onwuegbuzie 2004; and Mertens, 2005), which might be limiting to researchers in the social sciences.

In early 1970s educational researchers became unhappy with the positivist way of looking at the social world (Tashakkori and Teddlie, 1998). Researchers argued that problems in educational contexts are very complex and that truth cannot be accessed solely by using traditional experimental methods (Tashakkori and Teddlie, 1998; and Mertens, 2005). As a result the constructivist paradigm was proposed. LeCompte and Schensul (1999), Patton (2002), and Mertens (2005) point out that researchers located in the constructivist paradigm believe that there are multiple realities constructed by humans who experience the phenomenon of interest (i.e. reality is socially constructed). These authors all go on to say that to better understand the social world constructivist researchers have to be immersed in the social world rather than sticking to what they observe and measure. The

constructivists, therefore, tend to use a *"more personal, interactive mode of data collection"* (Mertens, 2005). This includes data-collecting methods such as interviews, observations, and document reviews (Mertens, 2005).

By the end of 1970s a third paradigm arose because of dissatisfaction of some researchers with both the positivist and constructivist paradigms, which they regarded as inflexible. Patton (1982, 188) says that commitment to only one paradigm is to be constrained by *"paradigmatic blinders"*. Patton (1980) proposed the paradigm of choices, which Reeves and Hedberg (2003) later called the eclectic – mixed methods – pragmatic paradigm. **Pragmatic** means *"advocating behaviour that is dictated more by practical consequences than by theory or dogma"* (Collins English Dictionary, 1991). Pragmatists believe that effectiveness should be used as the criterion for judging the value of research, that is, their belief system is based on practical choices. **Eclectic** refers to *"Selecting what seems best from various styles, doctrines, ideas, methods, etc"* (Collins English Dictionary, 1991). Eclectic and pragmatic researchers start with the problem and research questions to be answered, and then decide on methods that will offer the best opportunities for answering their research questions. This often means using mixed methods, which are expansive and creative and not limiting researchers to one way of looking at the social world (Johnson and Onwuegbuzie, 2004). Using mixed methods in one study affords researchers the opportunity to draw from the strengths of each approach to counteract the weaknesses of the other (Johnson and Onwuegbuzie, 2004). In so doing, one improves methodological rigour (Patton, 2002).

In this study the eclectic – mixed methods – pragmatic paradigm was used, but a shorter version of the name (pragmatic paradigm) was used, as is now more common (e.g. Mertens, 2005). The pragmatic paradigm enabled me to be flexible when looking at the social world, coming up with strategies of collecting data and analyzing data using methods that best addressed the study research questions.

3.2.2 Research approach used in this study

A survey approach was used in this study. Cohen, Manion and Morrison (2000) identify surveys as an approach in which data is gathered (using instruments such as questionnaires or interviews) from a group of individuals (a 'sample') in order to describe aspects such as opinions, attitudes or beliefs of a larger group (the 'population') of which the smaller group is a part. If the sample is large, and if it can be considered to be representative of the population, findings can be generalized to the larger population.

Fraenkel and Wallen (1990, 10) point out that a survey approach has the potential to provide researchers with a lot of data obtained from a sample. However, they warn that there are also challenges involved, *"ensuring that the questions to be answered, are clear and not misleading and getting a sufficient number of questionnaires completed and returned so that meaningful analyses can be made".*

3.3 DATA-GATHERING INSTRUMENTS: Activity-based questionnaires

Educational researchers working in the pragmatic paradigm select their data-gathering instruments based on which instruments offer the best opportunities for answering their research questions. A

wide range of educational problems are examined using questionnaires, interviews, and classroom observations (Gall, Borg and Gall, 1996). In an attempt to find out about *Life Sciences* teachers' concerns and needs about teaching evolution to Grade 12s I originally planned to administer questionnaires and conduct interviews so as to benefit from both types of data-gathering and in order to triangulate the data gathered. However, once I started analyzing the data from the questionnaires it was apparent that the data was more extensive than anticipated, and the interview aspect of the study was dropped. Administering questionnaires and conducting interviews would have made this study too big and might also have resulted in loss of focus.

Galfo (1975) describes questionnaires as data-gathering instruments used to obtain factual data, opinions, and attitudes in a way that there is no face-to-face interaction between the researcher and the respondent (as occurs in the case of interviews). This means that questionnaires may be administered to subjects beyond physical reach of the researcher. Leedy (1989, 142) refers to questionnaires as a *"totally impersonal probe"*, as researchers need not come into contact with the respondents.

Galfo (1975) and Schumacher and McMillan (1993) say that in educational research questionnaires are widely used data-gathering tools because they offer a number of advantages, but Galfo (1975) warns that questionnaires are often misused and abused in research as some researchers think that they are quick and easy methods of collecting data when in fact they require very careful design. Following are the advantages and disadvantages of questionnaires to be considered if questionnaires are to be utilized as effective methods of data collection.

3.3.1 Advantages of questionnaires

Leedy (1989) mentions that questionnaires offer many benefits if they are carefully and thoughtfully designed. The benefits are:

- They are relatively less expensive for gathering information compared to interviews (Galfo, 1975; Fraenkel and Wallen, 1990; McMillan and Schumacher, 2001; Opie, 2004).
- Questionnaires allow data to be gathered more quickly than interviews, so larger samples can be accessed (Fraenkel and Wallen, 1990).
- They are less personal, as the interviewer does not come face-to-face with the participants on an individual level, so anonymity can be maintained (Galfo, 1975; Gall *et al.*, 1996; Schumacher and McMillan, 2001). This means respondents more readily give honest answers to sensitive questions (such as some of those in this study). Gall *et al.* (1996) warn, however, that anonymity might be problematic when follow-ups are necessary.
- Questionnaires can easily be used to gather data from participants who are geographically widely spread, if posted to respondents (Fraenkel and Wallen, 1990; McMillan and Schumacher, 2001).

3.3.2 Disadvantages of using questionnaires

Like other data-gathering tools, there are limitations associated with using questionnaires.

- Constructing a good questionnaire is not as easy as it appears to everyone (Galfo, 1975). Sanders (1995) warns that poorly constructed questionnaires may lead to collection of inaccurate data characterized by reliability and validity problems, so questionnaires need to be carefully designed.
- Poor response rates is one of the challenges associated with using questionnaires (Galfo, 1975). McMillan and Schumacher (2001) point out that this becomes a problem particularly in mailed questionnaires. However, the problem of poor response rate was not encountered in this study as the questionnaires were administered and collected by the researcher during a workshop.
- In cases where a researcher is not present when respondents engage with the questionnaires,
  - probing and clarity of ambiguous questions becomes impossible (Schumacher and McMillan, 2001), and
  - *"there is less opportunity to encourage the cooperation of the respondents"* (Fraenkel and Wallen, 1990, 335).
- Another problem with using questionnaires is that respondents may answer the questions even if they are not familiar with the topic under investigation (Foddy, 1993), and this may affect data reliability and validity so the results of the study are of little use (Sanders, 1995).
- Fraenkel and Wallen (1990) and McMillan and Schumacher (2001) point out that questionnaires are not an appropriate data-gathering technique for illiterate people, as these people cannot read and write.

Bearing in mind the benefits of using questionnaires, in this study I decided to use questionnaires in spite of the disadvantages. It was for pragmatic reasons associated with time needed to administer questionnaires, and convenience, that questionnaires were chosen over interviews. Questionnaires offered the best opportunity for collecting data from *Life Sciences* teachers who came for workshops.

3.3.3 Advice about designing effective questionnaires

Leedy (1989, 143) says that many questionnaires *"are so inexpertly written that they bear the hallmarks of a quick, effortless attempt to gather some data"*. He points out that haphazard thinking about questionnaires results in poorly constructed questionnaires which are not of value in research. A number of authors claim that carefully constructed questionnaires can succeed in gathering data that is of value for research (i.e. data with high reliability and validity). They point out that well designed questionnaires require an understanding of some basics (i.e. important guidelines to consider when designing questionnaires). These basics include understanding:

- the general layout and formatting of questionnaires,
- how to word questions,
- the order of questions,
- the importance of ensuring appropriateness of the questions.

In this study I used suggestions from the literature to improve the quality of the questionnaires, which helped me to realize my specific research objectives. The following tables contain some guidelines drawn from various authors who provide advice about the "dos and don'ts" of questionnaire design.

Many authors agree that the physical appearance is important to encourage respondents to complete questionnaires, and hence provide more accurate data. A summary of their advice is given in Table 5.

Table 5: Advice on the general layout and format of the questionnaires

What to do	Reason	Authors
Questionnaires should be attractive (for example, use good quality coloured paper, or include appropriate graphics and diagrams where suitable).	The appearance of the questionnaires is important for capturing the interest of the respondents so they are keen to answer the questions.	Oppenheim (1966); Gay, (1981); Berdie and Anderson (1974); Fraenkel and Wallen (1990); Cohen and Manion (1994); and Sanders (1995)
Every questionnaire should have a heading that is short and meaningful to the respondent.	A questionnaire with a heading seems to be more credible than one without.	Berdie and Anderson (1974)
Make sure that the questionnaire is brief and concise.	Long questionnaires take too much time and effort to complete which may be a turn-off on the side of the respondents, and may result in low return rates.	Gay (1981); Fraenkel and Wallen (1990); and Cohen and Manion (1994)
Make instructions on how and where to answer brief and clear.	To reduce confusion that the respondents may face.	Fraenkel and Wallen (1990); and Cohen and Manion (1994)
Enough space for answering should be provided.	If there is not enough space, respondents cannot write all of their information and researchers lose out.	Fraenkel and Wallen (1990); and Cohen and Manion (1994)

The wording of questions is very important because it has a significant impact on how people respond to a questionnaire (Leedy, 1989; Gall *et al.*, 1996; and McMillan and Schumacher, 2001). Surprisingly, the effects of wording questions well are not clearly understood by some researchers (Walonick, 1993). Table 6 contains some guidelines to consider when wording questions, in order to produce a meaningful questionnaire.

Table 6: Advice on wording questions for questionnaires

Guideline	Reason	Authors
Language used should be simple.	Simple language reduces misunderstandings.	Leedy (1989)
Do not use jargon that may not be understood.	Respondents may be turned off and may decide not to respond, or may answer incorrectly, so that the reliability and validity of the data will be decreased.	Gall *et al.* (1996)
Make questions relevant to the respondents.	Relevant questions may keep the respondents interested and keen to respond.	Gall *et al.* (1996)
Avoid asking too many questions.	There are problems associated with questionnaires that are too long. Respondents may: - not answer any of the questionnaire, - give up half way, - get bored, and may end up randomly ticking answers, - not answer questions carefully.	Gall *et al.* (1996); McMillan and Schumacher (2001)
Do not ask leading questions.	Leading questions suggest possible answers. The questions might pressurize respondents to give answers that they do not really believe.	Oppenheim (1966); Foddy (1993)
Avoid negatively stated questions.	Negative words tend to be overlooked by respondents, who may therefore give opposite answers to what they intended.	McMillan and Schumacher (2001)
Do not ask double-barrelled questions.	These are questions which have two parts to them. They can be confusing as they require two independent answers.	McMillan and Schumacher (2001)

Several authors (e.g. Berdie and Anderson, 1974; and McMillan and Schumacher, 2001) claim that the order in which questions are presented can affect the way that people respond. They, and other authors, offer some suggestions regarding the order of questions (see Table 7).

Table 7: Advice about the order of the questions in questionnaires

What to do	Reason	Authors
Start with interesting and non-threatening questions and place sensitive or confidential questions at the end of the questionnaire.	Sensitive and confidential questions may be intimidating. Their early appearance may influence the respondents to decide to abandon completing the questionnaire. However, if they are located at the end respondents would have settled down and may be prepared to try them.	Berdie and Anderson (1974); and McMillan and Schumacher (2001)
Group questions that are similar together.	Similar questions keep the respondents in one mind-set at a time. The respondent will feel more comfortable to complete the questionnaire.	Walonick (1993)
Each question should follow comfortably from the previous question.	This ensures that a transition between questions is smooth. Questionnaires that jump from one topic to another feel disjointed and are unlikely to produce high response rates.	Walonick (1993)

Lastly, McMillan and Schumacher (2001) and other authors offer some advice on how to check the appropriateness of questionnaires before they are used in a study. Two important steps, face-validation and piloting of questionnaires, are important because they help improve the validity of the data obtained using the questionnaire, as discussed later in sections 3.3.5 and 3.3.6. A summary of advice is given in Table 8.

Table 8: Advice on how to ensure appropriateness of the questionnaires

What to do	Reason	Authors
Ask an expert to check on the draft questionnaire (i.e. face validate the questionnaire).	It ensures the appropriateness of the questions and language used, so the instrument is more likely to measure what it is intended to measure.	Oppenheim (1966); and McMillan and Schumacher (2001)
Pilot-test questionnaires before administration.	This helps researchers to test whether there are ambiguities with the questionnaires which make understanding of the questions difficult, and allows necessary changes to be made before the final administration.	Leedy (1989); Foddy (1993); and Gall *et al.* (1996)

3.3.4 Development of the activity-based questionnaires for this study

A special kind of questionnaire was developed and used for this study. Mashalaba and Sanders (2003) use the term "activity-based questionnaire" and explain these as a specific type of questionnaire used during in-service workshops for teachers. The questionnaires serve two purposes: *" firstly, they are used as reflective tasks to get teachers thinking, either before or after an activity, so that they can learn meaningfully by constructing their own ideas as part of the workshop activities, and, secondly, they are used to collect research data"* (Ngxola and Sanders, 2008, 801).

As discussed in section 3.3.3, before constructing the questionnaires the literature on how to design effective questionnaires was reviewed. This opened up new possibilities and new ways of looking at questionnaires which helped me to develop questionnaires with a deeper insight. A number of factors had to be considered to ensure that the questionnaires were carefully designed. The factors included presentation (i.e. appearance and layout) of the questionnaires, sequence of questions, and the type of questions used in each instrument (open-ended or closed-ended questions).

The questionnaire developed looked neat and attractive as coloured paper was used to arouse interest of the respondents and to facilitate administration. Cartoon-like diagrams were used to capture the interest of the respondents and to motivate them to complete the questionnaire, as advised by Sanders (1995). Questions were sequenced in a way that they linked to the activities of the workshop, and were kept short so that respondents did not get bored.

In this study both open-ended and closed-ended questions were used for the questionnaires. Each type of question has advantages and disadvantages. Cohen and Manion (1994) say that the main advantage in using open-ended questions is that they encourage respondents to express themselves freely using their own words rather than being limited to options provided in closed-ended questions. But the problem of using open-ended questions is that they are time-consuming in terms of completion, and the responses derived from them are not always easy to analyze (Foddy, 1993). Open-ended questions were used because in some instances I wanted teachers to give their opinions, without restricting them to choose from the predetermined responses.

Closed-ended questions may be answered quickly, and because they are precoded, data derived from using them is easier to analyze (Gay, 1981). Converse and Presser (1986, 33) argue that *"closed questions spell out the response options, they are more specific than open questions, and therefore more apt to communicate the same frame of reference to all respondents"*. However, McMillan and Schumacher (2001) contend that options provided by closed-ended questions may be restrictive, thus forcing the respondent to give inaccurate responses. In this study some closed-ended questions were included because they could be completed in a short space of time during the workshop. It would have been unethical of me to use more of the teachers' time as they were attending a workshop, and had their own agendas.

I first reviewed the research questions for my study in order to get an idea of what data was needed to answer the research questions, and I then worded the questions for the questionnaires.

Seven "activity-based questionnaires" were used to get the teachers thinking about their concerns and needs regarding the teaching of evolution for the first time. The questionnaires were incorporated into the workshop tasks as a means of collecting data from the teachers. Table 9, on the following page, lists the questionnaires developed and provides information on each questionnaire.

Table 9: Questionnaires and information related to the questionnaires

	Name of the questionnaire	No. of items	Question type	What it dealt with	Appendix number
1	Having to teach evolution as a school subject in 2008.	2	Open-ended questions	Identifying teachers' concerns about the teaching of evolution	C1
2	Do you think you know enough about evolution to teach it?	16	Likert-type questions	Teachers' own knowledge estimate of the fundamental concepts of evolution	C2
3	Explain what you think is meant by "evolution" in biology.	3	Open-ended question	The extent to which teachers understood the fundamental concept of evolution.	C3
4	Evolution quiz	18	True or false questions	Identifying teachers' misconceptions	C4
5	Case scenario for acquired characteristics	3	Paragraph answers	Inheritance of acquired characteristics	C5
6	The creation / evolution continuum of beliefs. Where do you stand?	11	Closed-ended questions	Identifying teachers' belief systems on the creation /evolution continuum of Scott	C6
7	What support do you feel you still need in order to feel confident about teaching evolution in 2008?	1	Open-ended question	Identifying teachers' needs	C7

Activity-based questionnaire 1: The aim of the activity was to identify teachers' concerns, bearing in mind that this was to be the first time evolution would be taught to matriculants in South Africa, and teachers were worried. This questionnaire had two questions. The first activity was completed at the start of the workshop to get the teachers to talk about how they feel about having to teach evolution. The activity did not immediately focus on what was worrying them, but a second question that focused on their worries was added. The questionnaire included speech bubbles for teachers to answer in (see Figure 4 below for an example).

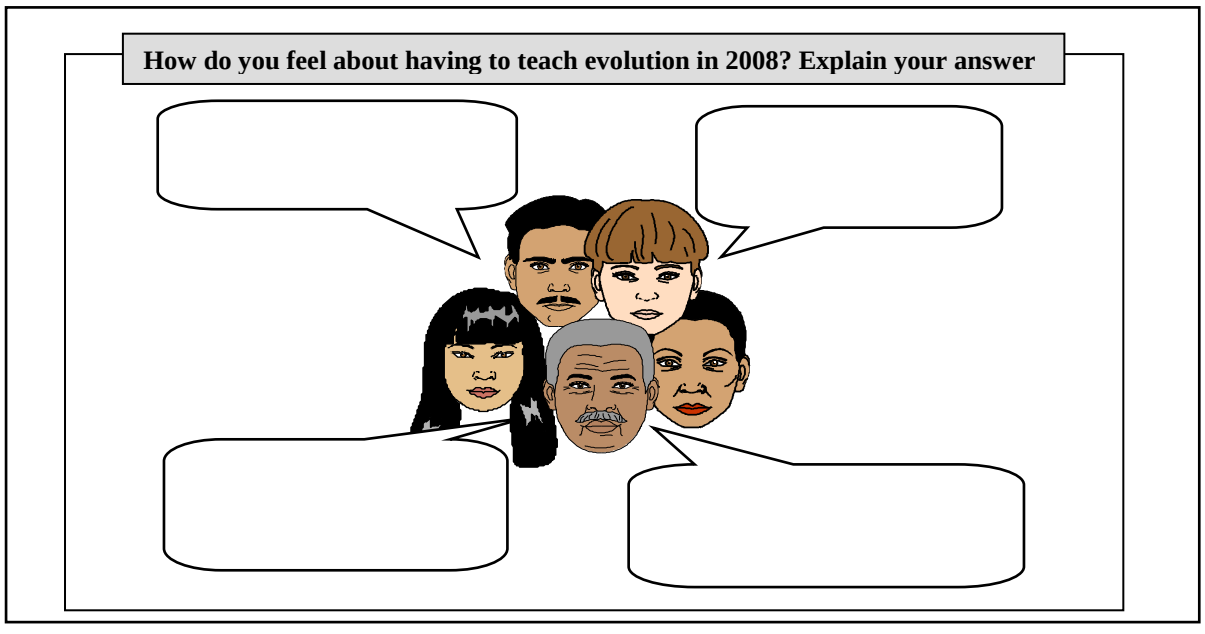


Figure 4: Example of the "speech-bubble" format used to solicit teachers' concerns

Activity-based questionnaire 2: The questionnaire was in a form of the table listing the evolution content from the curriculum statement. The table included a Likert-type response format (see Figure 5) which required teachers to estimate how adequate they believed their knowledge was about the fundamental concepts of evolution (i.e. biological evidence of evolution, fundamental aspects of fossil studies, origin of species, popular theories of mass extinction, and human evolution).

Do you think you know enough about evolution to teach it?

Please indicate your answer by placing a tick (T) in the relevant box or column.

How good is your detailed understanding of the fundamental concepts of evolution you are required to teach in 2008?

	Excellent	Good	Satisfactory	Poor
• **Biological evidence of evolution of populations and fundamental aspects of fossil studies**				
o Fossilization.				
o Fossils as evidence of ancient life.				
o Interpretation of the fossil record by means of morphological Divergence - homologous, analogous structures.				
• **Origin of species**				
o Definition of biological evolution				
o Evolution theories (Darwin's theory and Lamarck's theory.				
o Mutation and the part they play in evolution.				
o Variation (genotypic and phenotypic) in populations with examples e.g. White lions, cheetahs, Galapagos finches.				
o Natural selection.				
o Macroevolution – what it is and various lines of evolution (branches of the evolutionary tree) over geological time.				
o Formation of species at an (ecological, reproductive, and genetic level).				
o Inbreeding and outbreeding (with examples)				
• **Popular theories of mass extinction**				
o Continental drift, Ice age, volcano activity, heating and cooling of the atmosphere, and disease.				
o Extraterrestrial theories (explosion of star, meteor collision, comets).				
• **Cradle of humankind – South Africa**				
o Where are humans thought to have originated?				
o Differentiate between anthropology, palaeontology, and archaeology.				
o Possible origin of humankind on Earth.				

Figure 5: The Likert-response format used for Activity-based questionnaire 2

Research shows that teachers are not always "honest" in their responses, so teachers were involved in three more workshop activities to help them identify the adequacy of their estimates of their content knowledge.

Activity-based questionnaire 3 required teachers to think, and write down their understanding of biological evolution. **Activity-based questionnaire 4** was an activity to identify evolution misconceptions, and gave teachers an opportunity to see possible misconceptions they held. **Activity-based questionnaire 5** was an activity containing three inheritance scenarios, where each teacher was required to tick whether the children of the couple will inherit the characteristic or not, and space was provided so they could explain their answers. The purpose of the three questionnaires was to determine if the teachers had accurately estimated the adequacy of their own knowledge. After analyzing the data from Activity-based questionnaire 5 it appeared that the answers were too obvious, so this data were not included in Chapter 4.

Activity-based questionnaire 6: This was an activity on the creation / evolution continuum of beliefs. It asked teachers to indicate which belief category they fit into (see Appendix C6). The aim of the activity was to see if the teacher's belief systems and the concerns expressed seemed to show any trends. However, during the workshop the facilitator and I felt uncomfortable about collecting in such personal and confidential information, so we decided at the workshop not to collect that questionnaire for research, for ethical reasons.

Activity-based questionnaire 7: The activity required teachers to write down the support they thought they needed in order to teach evolution in 2008. This activity was important for in-service providers so they could plan their workshops to address the needs of the teachers.

3.3.5 Face validation of the questionnaires

As the questionnaires were being developed they were face-validated by my supervisor, who is an experienced staff member in research methods and who is an English first-language speaker. She checked whether the guidelines about designing an effective questionnaire had been followed. Most importantly the expert checked that:

- the questionnaires contained activities relevant to the workshop and which would help teachers reflect on their concerns and needs, so they could see the relevance of various workshop activities for preparing them to teach evolution effectively,
- the questions were easily understandable by English second-language speakers,
- the instructions were clear,
- the questions were logically sequenced,
- enough space had been provided to answer the questions,
- the questions used were likely to provide relevant data to answer the research questions, and that questions not pertinent to the goals of the study were excluded.

The process of face-validation involved iterative cycles of checking and improving the questionnaires based on the comments and advice I received.

3.3.6 Pilot testing

It is highly desirable to pilot test instruments before they are administered (Leedy, 1989; and McMillan and Schumacher, 2001). Piloting involves testing instruments on a small sample that is a representative of the population to be involved in a study, to identify potential inadequacies before the instrument is used in the main study (Galfo, 1975; and Gay *et al*., 1996). Instruments are piloted for the following reasons, to check:

- whether the wording of questions is clear so that respondents can easily understand what is being asked,
- whether the instructions for answering the questions are clear and not ambiguous,
- the time it takes the respondents to respond to the questions, so as to inform the final sample about the time it will take each questionnaire to be completed.

Originally I intended to pilot test the instruments, but due to shortness of time I could not conduct a pilot test. The date for the workshop had been set, and I spent a lot of time designing the questionnaires, and simply ran out of time.

3.3.7 Administration of the questionnaires

The context of the workshops in which data was collected will be discussed, followed by a discussion of the questionnaire administration.

Context of data collection: Data was gathered from teachers who were attending a series of workshops designed to alleviate teachers' fears regarding the controversial nature of evolution, and to prepare teachers to teach the topic of evolution. Informal talks I and my research group had with some biology teachers revealed that many of them felt they had not received adequate training on how to teach evolution. Furthermore none were aware of workshops planned in their districts to support them to teach evolution. In an attempt to equip teachers who had to teach evolution for the first time a lecturer at the University of the Witwatersrand conducted workshops with the purpose of preparing teachers to teach evolution, and to suggest ways of dealing with the possible controversy attached to teaching of evolution.

The first series of workshops was run in September 2007, three months before the new Grade 12 *Life Sciences* curriculum had to be implemented. It was run over three Saturdays (involving two Saturday mornings and one full-day Saturday field trip to the "Cradle of Humankind"). The field trip included a visit to the Sterkfontein Caves, where early hominin fossils (*Australopithecus africanus*) had been discovered. See Figure 6 for details.

The second workshop was run in February 2008 over four Saturdays. It was increased by adding one Saturday morning workshop to include other topics that were not covered in the first workshop. The workshop involved three Saturday mornings and one full-day Saturday field trip to the "Cradle of Humankind". Details of the sessions are shown in Figure 6.

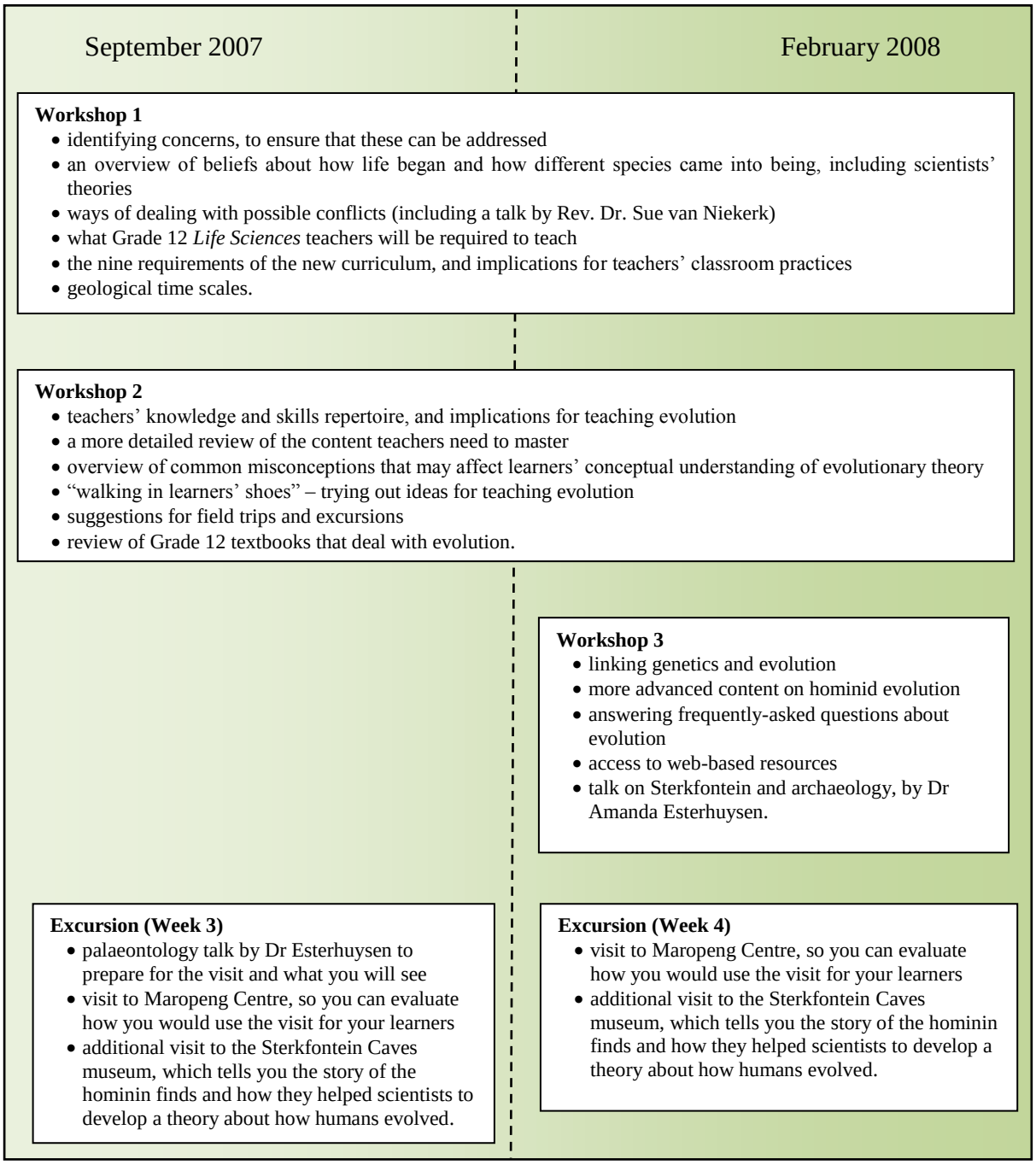


Figure 6: An outline of aspects covered in the September 2007 and February 2008 workshops

The excursion was part of the workshops so teachers could see the value of incorporating excursions in their teaching of evolution to provide a range of learning opportunities for their learners, and to help the teachers to plan an effective fieldtrip for their own learners.

There was a charge of seventy rand per session for the workshops. The amount was charged to cover basic costs of materials and refreshments. Our research group experience has shown that if workshops are free, many teachers who book do not arrive, possibly because they seem to value the opportunity less.

How administration of the questionnaires was done: The workshop facilitator took time to explain clearly the purpose of the workshop and the instructions on each activity-based questionnaire, even though the instructions were written in each questionnaire. As part of the workshop, the facilitator worked with teachers facilitating activities where teachers completed the questionnaires. For example, the first activity required the teachers to think and write down their feelings about having to teach evolution in 2008, and also teachers were asked to write their concerns about teaching evolution if they did not explain them in the first section. This was important as it had some implications for in-service providers who design professional development workshops that could address a common complaint from teachers that workshops were not relevant. If the Education Department knew about the teachers' concerns about the teaching of evolution they could have designed professional development workshops that addressed teachers' concerns. A second example was an activity which required teachers to indicate how adequate they believed their knowledge was about the fundamental concepts of evolution (i.e. biological evidence of evolution, fundamental aspects of fossil studies, origin of species, popular theories of mass extinction, and human evolution). The activity was useful for the teachers themselves, and for service-providers designing in-service training.

During the workshop teachers were seated in small groups of four or five, but were asked to treat the activities as individual tasks followed by discussions in groups or the whole class so as to get teachers thinking about something relevant to themselves or their practice.

After each activity was completed two post-graduate colleagues and I collected the questionnaires from each group, which had left them on the front corner of the table for collection while the workshop proceeded. The completed questionnaires were collected unobtrusively. One person photocopied them and the activity-based questionnaires were returned to the correct group so teachers could keep their work for their own use after the workshop. Each table was numbered and teachers were asked to put the table number and their initials on their own questionnaire to make it possible for questionnaires to be returned (anonymously) to the correct table, where teachers identified and collected their questionnaires. The timing of the collection of data was important (i.e. each questionnaire was collected before discussions started), so individual teacher's responses were obtained.

3.4 SAMPLING

Sampling refers to the process of choosing carefully from a larger population a smaller group which allows researchers to see the characteristics of the total population (Leedy, 1989). The sample should be chosen in a way that it is representative of the total population from which it is drawn, if the researcher wishes to generalize the results to the population. The manner in which the sample is selected is therefore important in research.

While random samples (in which each individual has an equal chance of being selected, and exhibits the characteristics that approximate those of a total population) are ideal, education researchers often use available groups of people as their research samples. This type of sampling is known as convenience sampling (Cohen and Manion, 1986).

The sample of teachers for my study was recruited by means of invitations circulated to about 300 secondary schools in the Johannesburg region using the Gauteng Department of Education (GDE) postal distribution system. The September 2007 invitation was sent only to GDE schools. In 2008 the invitation (see Appendix D) went out to GDE schools, and to Independent Education Board (IEB) schools via an e-mail distribution list for *Life Sciences* teachers. Teachers wishing to attend had to complete and fax a reply slip with their details, to facilitate planning for the workshop.

This meant that samples consisted of a convenience sample of teachers who volunteered to attend the workshops. One of the drawbacks of this type of sampling is that such groups may not be representative of the population from which they are drawn, so researchers must take care not to over generalize from such samples (Best, 1977). Volunteers may differ from non-volunteers in certain ways, for example, they may be the more committed teachers who are keen and more professional than the population they are meant to represent, and may give answers which may not be typical of all teachers. For the second workshop series it is possible that some teachers started to panic because they felt unprepared to teach the topic, and the time to teach evolution was approaching fast. So it is possible that my samples did not represent typical South African *Life Sciences* teachers and care needs to be taken not to generalize the findings to all South African teachers.

3.5 DATA ANALYSIS

According to Hatch (2002) data analysis involves a systematic search for meaning in the accumulated data. The researcher reduces, organizes and scrutinizes data which will in turn lead to explanations and interpretations (Hatch, 2002). In this study open-ended and closed-ended questions were used in the data gathering instruments, so two methods of analyzing the data were utilized.

The data were recorded on extensive spreadsheets at this stage, to facilitate counting and checking. In the case of the open-ended questions each identifiable unit for each teacher was recorded in tables and checked for accuracy, so that all coding could be done from a single sheet rather than having to shuffle through each of the 91 questionnaires out of the whole sample (i.e. 91 teachers) for each instrument.

Closed-ended questions were analyzed using frequency counts. The responses from the closed-ended questions were expressed in percentages. Open-ended questions were analyzed by means of open-coding (Strauss and Corbin, 1990). The process of developing the coding for data derived from the open-ended questions involved iterative cycles of checking and rechecking. The process included:

- going through a sample of questionnaires,
- identifying and listing points arising,
- sorting identified points into categories and sub-categories, which were then appropriately named.

Once a substantial list of points had been developed I checked to see if there was a need to merge similar points or to split categories that needed sub-dividing. The data were analyzed to a point where analyzing more questionnaires did not generate new categories. Then the coding system was ready to

be face validated. I asked the same experienced researcher to check if the coding system developed was comprehensive (covered all trends) and satisfactory (i.e. had logical and mutually exclusive categories and sub-categories). It was modified where inconsistencies were spotted.

After a satisfactory coding system had been established I went back and coded all questionnaires from the start, using the complete coding system. This included also the questionnaires used initially to develop the coding system. The coding involved underlining each identifiable idea in the teachers' written responses and fitting it into the appropriate category. After coding the data, it was then converted into quantitative data by counting the number of responses in each category. The coding was checked using inter-coder reliability with myself and my supervisor, who checked whether:

- every point in the response of each teacher had been identified,
- each new idea was individually and appropriately coded,
- counts were accurate.

3.6 RIGOUR

If education research is to benefit teachers in their practice, it should be rigorous to provide accurate results. 'Rigour' refers to quality of the research. Considering rigour encourages researchers to avoid typical pitfalls when they do their research. In this study two aspects to improve the quality of the research were considered, reliability and validity.

3.6.1 Reliability

Reliability refers to the replicability and consistency of results derived from a sample (Fraenkel and Wallen, 1990). If an instrument has a reliability problem this automatically means there will be validity problems. In this study several steps were taken to improve the reliability of results, thus improving rigour. The steps included checking (as described above) of:

- accuracy of data capture on spread sheets
- frequency counts
- intercoder reliability of the open-ended data.

3.6.2 Validity

Validity refers to the truth value of a method, test or research instrument (Fraenkel and Wallen, 1990). Validity also concerns the correctness and the meaningfulness of deductions made based on the information collected (Fraenkel and Wallen, 1990). A number of strategies to improve validity were employed in my study. Firstly, the instruments used in this study were face validated by a science education "expert" to minimize as many of the threats to validity as could be done by checking the instruments. Face validity is usually established by referring instruments to expert judgment (Anastasi, 1968). The expert checks to see whether the instrument is likely to measure what it is intended to measure and that other factors which might affect the trustworthiness of the results, as far

as possible, are eliminated. For my study the expert was asked to face validate all my instruments to check whether:

- the questions were clearly worded,
- the questions were likely to elicit the required information,
- the sequence of questions was logical and useful.

Secondly, the coding system I developed was face validated. The expert checked if the coding system developed for open-ended questions was comprehensive and satisfactory. Finally, as I wrote up my work I discussed the inferences I drew from my data with my supervisor, who is an experienced researcher, who checked that all my claims were supported by my research evidence.

3.7 ETHICAL ISSUES

Ethics has to do with the application of moral principles to prevent harming the subjects involved in research (Opie, 2004). A proposal with was sent Human Research Ethics Committee (Non-Medical) at the University of Witwatersrand for approval and to check that all the ethical requirements were met (see the letter of approval from the committee, with protocol number H0502, Appendix E). In this study ethics were considered in the following ways:

- During the workshop teachers were fully informed about the study and its purpose.
- Teachers were asked whether the activity-based questionnaires they had completed could be used for research purposes, and signed informed consent forms indicating their agreement.
- During the workshops teachers were asked to use only their table number and initials on their completed questionnaires. This was done so that I could return the activities to the teachers. I was able to use these to identify the teachers for follow-up purposes. However, I ensured anonymity of the participants by keeping a list with teachers' contact details separately. I used only numbers (e.g. #9.7, #5.8, #11.I8 etc.) when reporting quotes from individual teachers.
- Respondents were given contact details of the researcher and the facilitator so that they could consult the researcher should they have questions.

3.8 CONCLUDING REMARKS

The design of the research in this chapter was carefully planned. Decisions were carefully made based on extensive reading in the research literature. Steps were taken where possible to improve reliability and validity, although no piloting of the instruments was conducted.

The results obtained from the study will be presented and discussed in Chapter 4, which follows. In presenting the results, quotes from individual teachers are referenced using codes (e.g. #3.7). The codes are written in a way that the reader can identify between quotes made by 2007 respondents, and 2008 IEB or 2008 GDE respondents. Teachers in each sample were allocated a number e.g. #1 to #45 in 2007. The teacher codes from the 2007 sample are followed by a dot and number 7 representing year 2007 (e.g. #3.7 refer to teacher #3 from the 2007 sample). Because the 2008 sample was split into teachers from government schools (GDE schools) and private schools (IEB schools) I allocated

two codes as follows: The GDE quotes have a teacher number followed by a dot and number 8 representing year 2008 (e.g. #3.8 refer to teacher #3 from the GDE 2008 sample). The IEB quotes have a teacher number followed by a dot, a capital letter I (representing IEB) and number 8 representing year 2008 (e.g. #3.I8 refer to teacher #3 from the IEB 2008 sample).