Chapter Three

Research Methodology and a Pathway towards examining Scientific and Technological Literacy

3.1. Orientation to the Chapter

This chapter will illustrate the research methodologies that were employed in the pursuit of developing responses to the critical questions of this study. The chapter will reiterate the purpose and critical questions of this study, and then describe the general research methodology. The research instruments and research approaches will then be discussed. Research instruments included a questionnaire and a focus group interview schedule. The research instruments will be described in terms of the rationale for their inclusion, the process of developing them, and their validation. Research approaches entailed the use of qualitative strategies like the Strategic Objectives Learning Outcomes (SOLO) Taxonomy, which will be described from the literature, and then linked to this study in the form of questions pertaining to technological literacy. A profile of the sample will then be sketched, and then the research methodologies for each critical question will be described.

3.2. Critical Questions

Within the framework of the broad purpose of examining the scientific and technological literacy levels of students who were products of a traditional science curriculum, the research addressed the following critical questions:

3.2.1 What was the nature of the traditional science syllabi and teaching practices that the selected undergraduate physics students experienced at school, and how did it differ from transformational outcomes-based education in science and technology?

3.2.2 What were the levels of scientific literacy in the selected cohort of undergraduate physics students?

3.2.3 What were the levels of technological literacy in the selected cohort of undergraduate physics students?

At this juncture it is important to pause and reflect on why these critical questions were selected. Rather than make assumptions about the effects of the traditional curriculum on the science syllabi and on teaching and learning practices, the first critical question will examine the same and distill findings relative to the selected students. Further, this question embraces a comparison of the two paradigms to highlight the different emphases in policy and practice vis-à-vis learning and teaching in science. The second and third critical questions are included to determine the effects of the traditional science curriculum on scientific and technological literacy levels of the students. These two questions present science and technology in real life situations and will therefore expose the extent to which students use the information learned at school in their everyday lives. Further, these two questions embrace innovative, C2005 aligned approaches to measuring scientific and technological literacy levels. This alignment to C2005 represents a new dimension in the measurement of scientific and technological literacy levels. Moreover, the pursuit of critical questions two and three are important because "...scientific and technological literacy could become key planks within the platform concerned with raising of educational standards for all children (in South Africa)" (Parkinson 1999:11).

Each of the above critical questions required a different methodology. The general approach to the research methodology will first be illustrated before proceeding to describe the methodology associated with each critical question.

3.3. The Mixed Methodology Research Approach

The research methodology of this study can be described best as the "Mixed Methodology Design Model" of combining qualitative and quantitative research methods (Creswell 1994, cited in De Vos 1998:361). The mixed methodology method entails mixing aspects of the qualitative and quantitative paradigm at all or many methodological steps in the design.

De Vos (1998) contends that the mixed methodology approach to research adds complexity to a design and capitalizes on the merits of both the qualitative and quantitative paradigms. However, the mixed methodology approach to research requires a superior knowledge of both the quantitative and qualitative paradigms, links paradigms that may be unacceptable to some authors, and requires that the writer convey a combination of paradigms unfamiliar to many researchers. The quantitative and qualitative paradigms to research are briefly described below to develop a general understanding of these terms in the context of this study.

Reid and Smith (1990, cited in De Vos 1998) maintain that quantitative research approaches to research place emphasis on objectivity and the analysis entails statistical breakdowns of the distribution of the variables and the use of statistical methods to determine relationships or differences between the variables. Conversely, qualitative research approaches emphasize subjectivity (a phenomenological approach) by using the subjects' views as the principal data source. The methodology of the two approaches also differs with the former favouring the rating scales and frequency counts, while the latter is inclined towards unstructured interviews and in anthropological studies particularly, the use of participant observation.

In this study the quantitative focus of the research manifests itself in various ways. For example, the codification of student responses in the questionnaire followed by the data capture and the subsequent generation of frequency tables. The data were then used for descriptive purposes to describe the sample, to describe the frequency of the different teaching and learning experiences of the students. The data on scientific and technological literacy were also tested for normality. Various parametric tests were then administered to establish relationships between variables. For example, a multiple analysis of variables (MANOVA) test was administered to establish which contextual factors are the best predictors of scientific and technological literacy. Where necessary, graphics in the form of pie charts and bar graphs were used to accentuate the findings.

The qualitative focus of the research was evident in the use of open-ended questions in parts of the questionnaire; the use of semi-structured interviews which is a phenomenological approach that aims to interpret performance through the lenses of the students; and the use of actual student responses to corroborate findings generated in the quantitative analysis.

In this study the two paradigms were inextricably linked in the questionnaire. The questionnaire served as the catalyst for yielding both quantitative and qualitative data. The questionnaire blended the quantitative elements of the numerical ratings of scientific literacy with the qualitative open-ended responses pertaining to the demonstration of scientific and technological literacy outcomes.

A more illustrated account of the qualitative and quantitative features of this study will surface in the descriptions of the methodologies associated with each of the critical questions below. Before providing these descriptions of the methodologies, an overview of the research instruments (a questionnaire and a focus group interview schedule) and the qualitative research approach (SOLO Taxonomy) used in this study is provided.

3.4. Discussion of Research Instruments and Approaches

3.4.1. Research Instrumentation

There were two research instruments used in this study, i.e. a questionnaire and a focus group interview schedule. The questionnaire was the primary source of data for all three critical questions in this study and also elicited data that was used to develop a profile of the students. The questionnaire collected information about first year students' levels of scientific literacy (Part 1), their levels of technological literacy (Part 2), and biographical information about the respondents (Part 3) [see Appendix 1]. The focus group interview schedule (see Appendix 2) was used largely in the synthesis component of this study to confirm or reject findings that emerged from the analysis of data generated in the questionnaire.

The questionnaire will be described in terms of the rationale for developing it, the process of designing the questionnaire, and the validation of the questionnaire. Thereafter, a similar description will unfold for the focus group interview schedule, albeit less extensive. The development of the questionnaire was an important part in this study; therefore, it consumes a significant part of the description on research instrumentation.

3.4.1.1. Rationale for Developing the Questionnaire

As mentioned in chapter one, the first innovation of this study is to develop new insights and methods to evaluate science and technology literacy levels of learners in South Africa. This study adds a new dimension to previous similar studies in South Africa (Laugksch 1994) in that it resonates with the Outcomes–Based Education (OBE) paradigm that is currently in vogue in South Africa. This innovation is manifested in the questionnaire.

There are a variety of ways to collect information to establish whether students are capable of demonstrating the science and technology outcomes as envisioned by C2005. The methods include, amongst others, personal interviews (structured or unstructured) and observation of the actual demonstration of science and technology outcomes by the students. The intention of this study was to use a large sample and therefore the above methods of collecting data were impractical and time consuming. The most convenient way to collect information about scientific and technological literacy levels of a fairly large population of students (n = 171) was to administer a pencil and paper test. Hence, the questionnaire was developed.

As mentioned above, there were three parts to the questionnaire. The first part of the questionnaire pertained to scientific literacy levels of the students. This part was developed in response to a major criticism against C2005, i.e. its deliberate silence on content, and the poor conceptual knowledge of educators and learners [see Chisholm et al (2000) and Taylor & Vinjevold (1999)]. Therefore, one had to measure the conceptual knowledge of the students in science. However, the questions on scientific literacy in this study were not confined to conceptual knowledge exclusively, they included a deliberate focus on the application of these concepts in real life situations. This interpretation of scientific literacy is a combination of Shen's (1975, cited in Shamos 1995) civic scientific literacy and practical scientific literacy concepts. It entails having a knowledge that would enable citizens to become more aware of science-related issues, so that the quality of their lives would improve by them applying scientific principles and they would have the power to affect public and technological policy.

The second part of the questionnaire pertained to the technological literacy levels of the students. The rationale for using the questionnaire was to elicit qualitative, open-ended responses from the students on questions related to the technology outcomes as envisioned in the C2005. The students were presented with real life scenarios to test the demonstration of the outcomes. Thereafter, the responses were classified and analyzed using the SOLO Taxonomy (described below).

Both the first and the second part of this questionnaire mirrored the Laugksch (1994) study. He developed a plethora of science and technology literacy questions related to, amongst others, the solar system; the nature of science; chemical reactions; intracellular processes; evolution; and forces. The Laugksch (1994) questionnaire served as a reliable indicator of scientific and technological literacy in a theoretical context. However, this study added a new dimension to studies like the Laugksch (1994) study because there is a deliberate focus on the application of these concepts in real life situations.

The third part of the questionnaire focused on biographical details. This component was included in the questionnaire as it solicited information that went beyond what was available in the personal records of the students at the University of Pretoria. For example, information about the availability and condition of resources at the schools attended by the students, and the kinds of teaching and learning experiences of the students at school, were not available at the University of Pretoria. The information from part three was used to develop a comprehensive profile of the students as described below.

3.4.1.2. The Process of Developing the Questionnaire

The development of the questionnaire was an extremely iterative process. There were several versions of the instrument, which were reviewed jointly by the supervisor and statisticians from the STATOMET at the University of Pretoria. The reviews ensured that the instrument was clearly focused to collect only data that was necessary to answer the critical questions, and that it was statistically viable.

To measure the scientific literacy of the subjects, one simply could not arbitrarily select questions pertaining to a variety of science themes and administer them. Rather, the selection of questions was informed by the guidelines endorsed in the Discussion Document of C2005 (DOE 1997a). For example, there were four themes in the Natural Sciences and these themes formed the basis of the questions on scientific and technological literacy.
The four themes were:

- The planet Earth and Beyond;
- Life and Living;
- Energy and Change; and
- Matter and Materials.

A pool of multiple-choice questions was developed from which the supervisor and the author jointly distilled the most appropriate questions. The approach was not to overwhelm the respondents with a battery of questions but to elicit their responses to a minimum of twenty questions on scientific literacy. The scientific literacy questions were based on science concepts like global warming, the force of gravity, inertia, friction, genetic make-up, the Human Immuno-deficiency (HI) virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS), and seasonal change. These concepts were consistent with the four themes of Natural Science as listed above, and also with the corresponding concepts outlined in the Discussion Document of C2005 (DOE 1997a). The nature of the questions was guided by some of the specific outcomes of the Natural Sciences learning area, namely: "demonstrate an understanding of concepts and principles, and acquired knowledge in the Natural Sciences; use scientific knowledge and skills to solve problems in innovative ways; and use scientific knowledge and skills to support responsible decision-making" (ibid:134).

The questions were mainly at the comprehension and application levels of Bloom's taxonomy of educational objectives although some questions were at the knowledge level. The levels of the questions will be discussed in chapter five. The Grade 12 Physical Science and Biology Syllabi, as well as science concepts that were being given attention by the media at the time, e.g. HIV/AIDS, served as references while questions were being developed. Two questions are listed to illustrate the nature of the multiple-choice questions:

The genetic make-up of an offspring is…

Choices

Predetermined in the mother	**Predetermined in the father**	**Dependent on the crossing over of chromosomes**	**Dependent on the time of fertilization**
1	2	3	4

The energy changes which take place when a light is switched on:

Choices

Electrical to heat	**Electrical to light**	**Electrical to heat to light**	**heat to light**
1	2	3	4

These two examples illustrate the closed, knowledge-based nature of the scientific literacy test, which also incorporated the application of science to everyday life situations. These questions were distinctly different from the open-ended nature of the technological literacy questions discussed below.

Before describing the processes associated with the development of the technological literacy questions, the working definition of the concept, which was developed in chapter two, will be reiterated. For the purposes of this study, a technologically literate person is someone who critically "analyzes the pros and cons of any technological development (using reliable research methods), to examine its potential benefits (and demerits), its potential costs, and to perceive the underlying political and social forces (especially values) driving the development" (Fleming 1987, cited in Saskatchewan Education 2000:1).

To measure the technological literacy of the subjects, the guiding principle was to measure the extent to which the specific outcomes for technology were demonstrated. According to the Discussion Document of C2005 (DOE 1997a), there were seven specific outcomes for technology; i.e. Learners will be able to:

1. Understand and apply the technological process to solve problems and satisfy needs and wants.
2. Apply a range of technological knowledge and skills ethically and responsibly.
3. Access, process and use data for technological purposes.
4. Select and evaluate products and systems.
5. Demonstrate an understanding of how different societies create and adapt technological solutions to problems.
6. Demonstrate an understanding of the impact of technology.
7. Demonstrate an understanding of how technology might reflect different biases, and create responsible and ethical strategies to address them.

Each of these specific outcomes are in sync with critical outcome 6 of C2005 and will thus serve to illustrate how learners use science and technology effectively and critically showing responsibility towards the environments and the health of others. The specific outcomes also dovetail with critical outcomes 1, 4 and 7 as learners need to:

(1) Identify and solve problems, and make decisions using critical and creative thinking;
(4) Collect, analyze, organize and critically evaluate information; and
(7) Demonstrate an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation.

Six questions, based on each of the above seven specific outcomes, were developed to test the technological literacy levels of the students. Each of the six questions corresponded with a specific outcome in technology except for one of the questions, which addressed both specific outcomes one and two. As was the case for the scientific literacy questions, there were several versions of these questions, which were reviewed by the supervisor. Moreover, in the development of these six questions, the nature of the SOLO taxonomy had to be considered. For example, you cannot provide questions to which there is a one-word answer, as that would limit the response to a low classification level in the SOLO taxonomy even though it may be a correct response. Moreover, the responses to the qualitative technological literacy questions had to be coded, and for this, guidance was provided by STATOMET at the University of Pretoria.

Two of the questions or tasks are reflected below, and are preceded by the specific outcome/s (SO) that they addressed.

SO3. **Access, process and use data for technological purposes.**

Task: *The graph below reflects electricity consumption for a family of four in a standard three-bedroom home in Gauteng for a three-month period. Sketch changes to the shape of the graph for the period December to February. Support your proposed changes with valid reasons.*
Provide reasons for changes to the shape of the graph:
(See Appendix 1 for the shape of the graph)

SO4. **Select and evaluate products and systems.**

Task: *Briefly describe the technological factors that you would take into consideration before purchasing a cell phone, and justify your selection of factors?*

The responses to the above questions were all qualitatively different and the classification of the responses was informed by the SOLO Taxonomy, which is described below.

The third part of the questionnaire collected data on fairly common biographical details of students like their ages and former schools, which was a fairly routine exercise. However, a deliberate attempt was made to acquire insights into additional biographical features like the medium of instruction in the science classes at schools, or the number of students who were in their matric science classes. These data were used to develop an embellished profile of the students as outlined in the description of the sample below. The third part of the questionnaire also helped to provide insights into the nature of the teaching and learning experiences of the students. For example, students were asked to list the frequency with which they experienced chalk and talk as a method of teaching or memorizing notes as a method of learning. These insights on teaching and learning experiences will be used to develop a comprehensive response to the critical question one on the nature of the actual teaching and learning experiences of the students.

3.4.1.3. Validation of the Questionnaire

The questionnaire was validated in various ways. First, the supervisor validated the content and the nature of the questions. Amongst other things, the supervisor ensured that the questions were consistent with the level of testing first year physics students, that the questions were related to the relevant outcomes, and most importantly that the questions were linked to the real life experiences of the students. Second, the supervisor and statisticians from STATOMET at the University of the Pretoria validated the structure of the questionnaire. Thirdly, and perhaps this was the acid test for validity of the questionnaire, it was piloted with ten Technology Education students from the Faculty of Education at the University of Pretoria in the third week of their course. The responses of the Technology Education students were used to refine the instrument. For example, the first language choices were increased to include more African languages.

Thus, the questionnaire has been described with regard to the rationale for its use, the processes associated with its development, and the validation of the instrument. A similar kind of discussion now follows on the focus group interview schedule.

3.4.1.4. Rationale for the Focus Group Interview Schedule

As mentioned above, the focus group interview schedule (see Appendix 2) was used largely in the synthesis component of this study to confirm or reject findings that emerged from the analysis of data generated from the questionnaire. The principal purpose of the focus group interview was to relate the perceptions of homogenous groups of students to their actual performance on the scientific and technology literacy tests. Homogenous groups of students included those with similar levels of scientific and technological literacy. For example, all students with a scientific literacy score of less than or equal to 8 out of 20, and a technological literacy mean of 1. These combinations will be described in greater detail in the descriptions of the methodologies associated with critical questions two and three below.

The focus group interview was used because it blends in with the cooperative approach to learning that is endorsed by C2005. Rather than expose students to a one-on-one interview (structured or semi-structured) which can be intimidating, student interaction in homogenous groups was encouraged to elicit joint responses from students.

3.4.1.5. The Process of Developing the Focus Group Interview Schedule

The first challenge in developing the focus group interview schedule was to select the students with similar scientific and technological literacy levels. The statisticians from STATOMET were extremely helpful in this regard. A stratified sampling method was used to selecting students who participated in the focus group interviews. The strata were based on similar performance on the scientific and technological literacy tests. The statisticians identified at least 65 students in the different strata. 32 of these students volunteered to participate in the focus group interviews. Thus, 19 percent of the sample participated in the focus group interviews.

The introduction of the focus group interview focused on roles and responsibilities of the students. This logistical arrangement was necessary to facilitate the actual discussions and responses in the homogenous groups. The students were requested to quickly decide how the following roles would be assigned in their groups:

Gatekeeper:	ensures that each member has an equal opportunity to participate.
Scribe:	summarizes the main points raised in the discussions.

An observer was assigned to each of the groups. The observer did not participate in the discussion but used an observation schedule (see Appendix 2) to record some of the group dynamics. These dynamics included: the extent to which each member of the group participated in the discussions, how consensus was reached in the group, and the kinds of challenges encountered in each of the groups. Additionally, the observer rated the students on the use of scientific and technological concepts. The observer was also the timekeeper in each group, i.e. ensured that the same amount of time was allocated to each question.

The focus group interview tended to be more phenomenological and probed the students on their rationalities to explain their performance. The focus group interview schedule actually mirrored this study in that the following were examined through the lenses of homogenous groups of students:

a) the concepts scientific and technological literacy;
b) how these concepts can be measured; and
c) the application of these concepts in everyday life.

With regard to students conceptions of scientific and technological literacy, they were required to provide definitions of these terms after discussing them, and then to explain how they would determine whether a friend, colleague or parent is a) scientifically literate, and b) technologically literate.

Students were provided with an example of how science is used in our daily lives and asked to provide an example of their own. The most interesting question in the interview was: "If you were the Minister of Arts, Culture, Science and Technology, what changes would you introduce in society to enable all citizens to become scientific and technological literate? "

Finally, students were required to develop joint responses to three of the technological literacy questions that featured in the questionnaire. These questions pertained to whether AZT should be made available to pregnant women, the technological factors taken into account when choosing a cell phone, and the impact the Internet has had on society.

3.4.1.6. The Validation of the Focus Group Interview Schedule

The supervisor, who made several recommendations that helped to refine the instrument, validated the content and the structure of the focus group interview schedule. These recommendations related to defining the roles of the students while they were in groups, and the avoidance of too much responsibility in the group. Hence, the concept of an observer emerged. The supervisor also inspired some of the questions in the interview schedule.

Both instruments (the questionnaire and the focus group interview schedule) have now been discussed in terms of their rationale, the process of development and their validation. All that is left in this component is to describe the qualitative research approach of this study, namely, the Strategic Objectives Learning Outcomes Taxonomy.

3.4.2. The Strategic Objectives Learning Outcomes (SOLO) Taxonomy

As mentioned above, the responses to the questions on technological literacy were all open-ended and qualitatively different. Such responses were classified and analyzed using the SOLO Taxonomy. Biggs & Tefler (1987) perceive the SOLO Taxonomy as a classification system that may be used for setting curriculum objectives, and for evaluating the quality of learning outcomes.

There are three levels of complexity within the target mode:

- UNISTRUCTURAL;
- MULTISTRUCTURAL; and
- RELATIONAL.

The target mode is sandwiched by two extremes or levels. At a lower level of abstraction than the target mode is the PRESTRUCTURAL response. At a higher level of abstraction than the target mode is the EXTENDED ABSTRACT response.

Biggs & Collis (1982, cited in Biggs & Tefler 1987) showed that over a large variety of mainly school-based tasks, there is a consistent sequence in the way aspects of the tasks become related together. As alluded to above, the cycle has five general levels. In order of increasing complexity Biggs & Tefler (1987:177) define the levels thus:

> *"PRESTRUCTURAL: The task is engaged but the learner is distracted or misled by an irrelevant aspect belonging to a previous stage or mode. (The outcomes are inadequate or simply incorrect.)*
> *UNISTRUCTURAL: The learner focuses on the relevant domain and picks up on one aspect to work on.*
> *MULTISTRUCTURAL: The learner picks up more and more correct or relevant aspects but does not integrate them together.*
> *RELATIONAL: The learner now integrates the parts with each other so that the whole has a coherent structure and meaning.*
> *EXTENDED ABSTRACT: The learner now generalizes the structure to take in new and more abstract features representing a higher mode of operation."*

Killen (2000:8) states that in prestructural responses there is no logical connection between the task (question) and the response. The learner either does not want to engage with the task ("I don't know", "That's a dumb question"), simply repeats the information in the question, or guesses the answer. Killen (2000) goes on to define a unistructural response as one which draws a correct conclusion, but is based on only one aspect of the data. In a multistructural response, two or more pieces of data are used to reach a correct conclusion while a relational response uses an overall concept to account for various bits of data. And, extended abstract responses go beyond what has been taught and use logical deduction to frame the answer.

So, the responses provided by the subjects in this study to the questions on technological literacy were classified using the above five categories. There was a deliberate attempt in developing the questions to avoid prompting unistructural responses. Simply stated, the classification corresponded with a scoring of the responses from 1 to 5, where prestructural, incorrect or irrelevant responses were given a score of 1, and extended abstract responses were scored 5. Target mode responses were scored 2, 3 and 4 depending on whether they were unistructural, multistructural or relational respectively. Of course, a level of consistency was required to score these responses. To this end, the supervisor conducted random consistency checks after the all the responses were scored. Additionally, to ensure that a subjective bias was not attached to the scoring, the author and the supervisor reviewed some of the responses jointly before the author proceeded to score the entire batch of questionnaires.

The use of the SOLO taxonomy manifests the qualitative dimension of this study. In fact, the use of the SOLO taxonomy to classify responses to questions that address specific outcomes in technology has not been explored in South Africa. This is why the use of the SOLO taxonomy is labelled as the second innovation in this study. Killen (2000) argues that in order to provide more useful feedback to learners, we need a systematic way of describing how we arrived at our qualitative judgments and he proposes the SOLO taxonomy as one system to achieve this outcome.

The discussion of the research instruments and approaches was extensive, but necessary. It formed the fountain from which data relevant to the three critical questions will spring. The focus will now turn to descriptive statistics to provide a profile of the students, and then a description of the methodologies of the three critical questions will follow. It must be emphasized that foregoing discussions on research instruments and approaches have covered many aspects of the methodologies related to critical questions two and three. Therefore, the methodological descriptions for these two critical questions will not be as extensive as that for critical question one.

3.5. The Sample

An overview of the sample is presented so as to develop insights into some of the biographical details of the students. These numerical and graphical snapshots provided in the sample description below will help the reader to identify with the students as well as to understand the performance of the students in the scientific and technology literacy tests.

The target population in this study was the cohort of physics undergraduate students at the University of Pretoria in their first year of study in the year 2000. The target population was requested to participate in the study by the Physics Department at the University of Pretoria. From this population, a convenience sample of 171 students volunteered to participate in the study. The sample included first year students with Physics as a major (n = 100) as well students in the extended programme (n= 71) which spreads the first year curriculum over two years. The courses pursued by each of these groups were Physics 171 and 101 respectively. The sample was fully representative (84 %) of first year Physics 171 and 101 students at the University of Pretoria in the year 2000.

The sample will now be described in terms of eight main biographical features. The latter pertain to the students' genders, ages, first languages (the language they used most often), locations of their schools, availability and conditions of school resources, achievement scores in the matriculation examination, the number of pupils in their matriculation science classes, and the medium of instruction in matric science classes.

Firstly, there was a distinct imbalance in the gender distribution of the sample. As illustrated in Figure 3.1. below, the sample included 68 % males and 32 % females, i.e. there were 116 males and 54 females (one student declined to list gender and that silence was respected). The imbalance in the distribution suggests that males have a greater preference for physics.

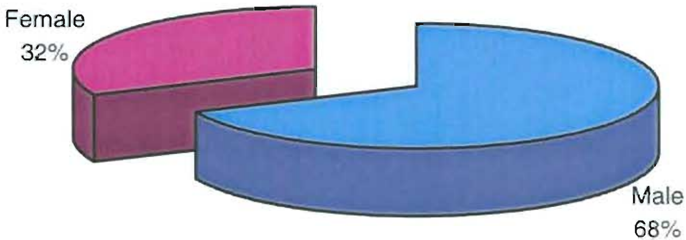

Figure 3.1. The Gender Distribution of the Sample

Secondly, the ages of the students ranged from 17 to 24 as shown in Figure 3.2. below. Most of the students were either 18 (43 %) or 19 (35 %) years old. A small percentage of students featured in the age categories of 17 (5 %) and 20 (8%). Although the range of student ages extends through to 24, there were very few students in the higher age bracket. Only 9 percent of the sample featured in the age bracket 21 to 24 (15 students). So by and large, the sample included students who had recently completed their schooling careers.

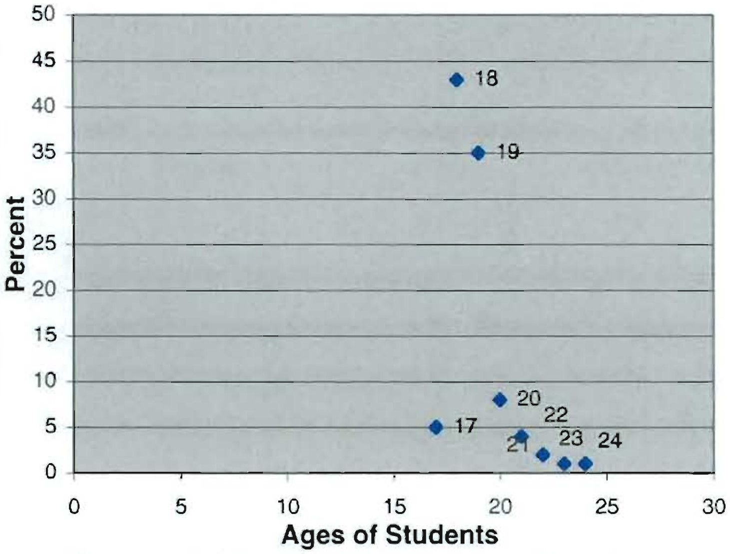

Figure 3.2. The Age Distribution of the Sample

Thirdly, there were two variables in this study that were used as proxy indicators to determine the racial distribution of the sample. These variables related to the first language of the students and the former department of education that the student's school was affiliated to.

The first language of a student was defined in the questionnaire as the language that was used most often by the student. It was assumed that the first language of the students would hint at the race of the students. This was indeed risky, as students who were of Indian or Coloured origin would be classified as White if they listed either English or Afrikaans as their first language. Based on observations made during the administering of the questionnaire, there was sprinkling of students who were Indian or Coloured. There was even one student who was of German origin. Moreover, some African students might use English or Afrikaans most often and hence list it as their first language according to the definition provided in the questionnaire. Therefore, when the first languages and corresponding races are disaggregated and discussed below, these anomalies must be noted.

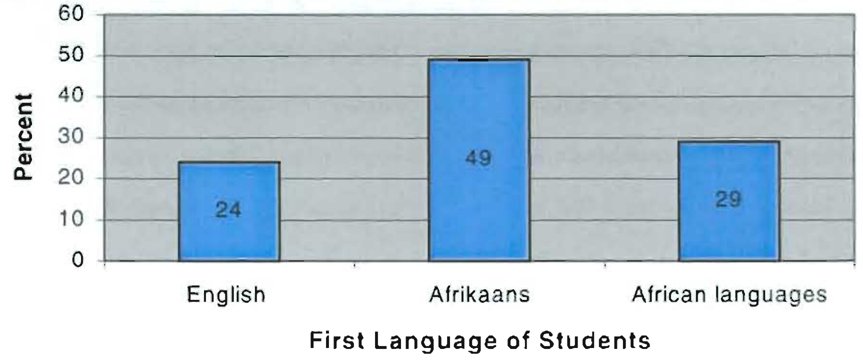

Figure 3.3. The First Language Distribution of the Sample

Figure 3.3. indicates that nearly half of the students (49 %) in this study used Afrikaans as their first language, and about one quarter (24 %) of them used English as their first language. The remaining students (29 %) listed indigenous languages like IsiZulu, Setswana, IsiKhosa, and Sepedi as their first language. It would be premature and incomplete to use the above distributions of first languages exclusively as predictors of race. However, when this data is combined with the data on the former departments of education, a more accurate set of inferences can be made.

Most of the schools that were attended by the students in the sample were formerly affiliated to one of the 19 education departments that existed in South Africa, except if they were private schools. These departments included, amongst others, the House of Assembly (HOA), the House of Representatives (HOR), the House of Delegates (HOD), the Department of Education and Training (DET), the Department of Education and Culture (DEC, formerly homeland schools). These departments were segregated according to race (e.g. HOR schools were exclusively Coloured in racial composition), and hence can verify claims of racial distribution intimated above in the discussion on first languages. However, once again there exists the possibility of an inaccurate inference. For example, if a student of colour attended a school which was formerly an HOA school, that student would be assumed to be White as HOA schools remain largely White.

Most of the students in the sample (58 %) were from former HOA schools; hence it can be assumed that they were White students. However, it was implicit from the combined percent of students whose first language was English and Afrikaans speaking that 73 percent of the students in this sample were White. The differential is satisfied, in part, by the 10 percent of the students in the sample who listed private schools as their former schools. This ten percent cannot be exclusively White as African, Indian and Coloured children also attend private schools. It is therefore assumed that half of the private school attendees were White, and in total about 63 percent of the sample were White.

Figure 3.3. also intimates that 29 percent of the students were African. This may well be true but the former department of education data suggests that the composition of African students was closer to 25 percent. The average of these two percentages leads the writer to assume that there were 27 percent African students in the sample. Only six students (4 %) were from the HOD, and therefore Indian. There were ten students (6 %) from the HOR, and therefore Coloured. The synthesis on the racial distribution of students in the sample is summarized in Table 3.1. below.

Racial Grouping	Percent
White	63
African	27
Coloured	4
Indian	6

Table 3.1. The Racial Composition of the Sample

Fourthly, the sample population was also analyzed in terms of the locations of the schools that were attended by the students (see Figure 3.4. below). Most of the students were from schools in the suburbs (42 %) and the cities (27 %). Only 15 percent of the students attended township schools. Farm schools served as feeder schools for just 5 percent of the sample. Therefore, the combined percentage of school locations of the four pre-selected options in the questionnaire was 89 percent. This left a gap of about 11 percent for students who listed an alternate location of their school. These students were either silent in their responses, or ambiguous by stating that their schools were rural which could mean township or farm schools.

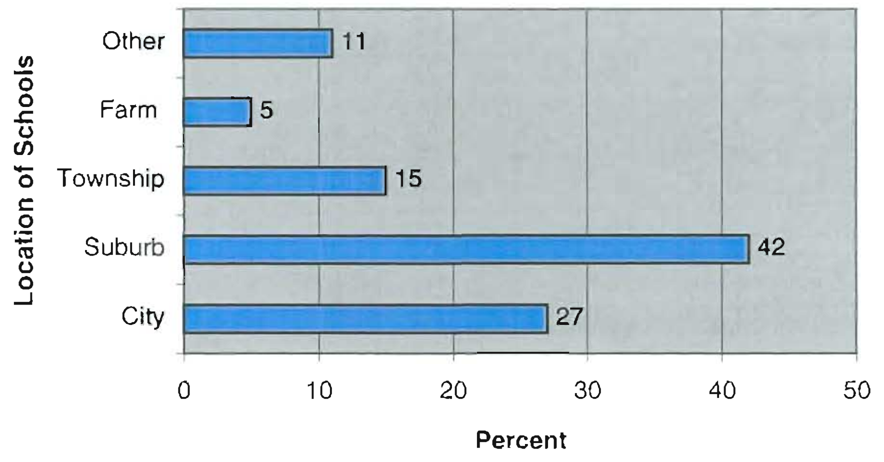

Figure 3.4. The Locations of Schools in the Sample

Fifthly, given that most of the schools were in the suburbs or cities, and not in the townships or farms, it was not surprising to learn that most of the schools were well resourced. Figure 3.5. below summarizes the availability and condition of resources at schools. Figure 3.5. shows that more than 70 percent of all resources (electricity, laboratories, textbook supply, teaching aids, and furniture) were of excellent or good quality. Electricity was available in all but 2 percent of the schools, and in only 4 percent of the schools was it rated as poor. Laboratories were generally available and in good (47 %) or excellent (27 %) condition except in 19 percent of the schools where they were poorly equipped. Laboratories were not available in 7 percent of the schools. Textbooks were generally in good supply with the exception of 7 percent of the schools which had none, 11 percent rated the textbooks as poor. A similar situation prevailed for teaching aids. All schools had furniture, and just 7 percent of the students rated these as poor.

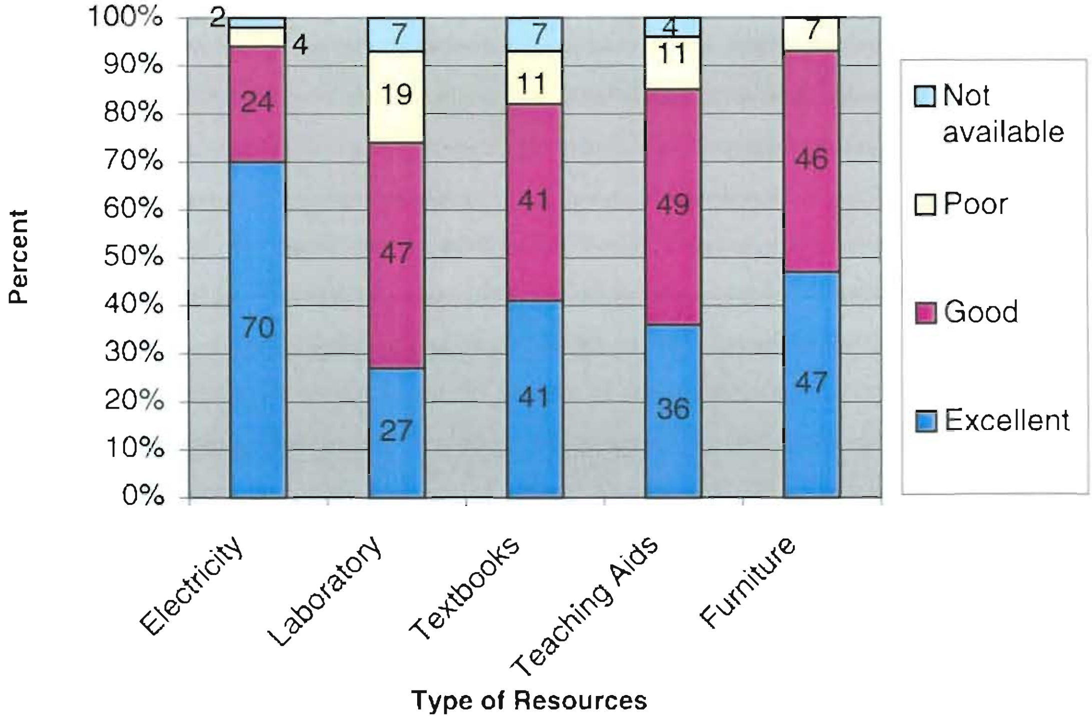

Figure 3.5. The Availability and Condition of Resources in Schools

Sixthly, the fact that the schools were generally well resourced suggests that achievement scores in the matriculation examinations were generally of a good quality. This is indeed true as indicated in Figure 3.6. below. In the discussion that follows on the matric symbols, the corresponding scores have been listed in Table 3.2. below.

Symbol	Score(Percent)
A	80-100
B	70-79
C	60-69
D	50-59
E	40-49
F	33-39
G	30-33
H	<30

Table 3.2. Matric Symbols and Corresponding Scores

In the six core subjects listed in Figure 3.6. there was a negligible percentage of under performing students (those with 'f' and 'g' symbols). Some of the students even scored distinctions in the six core subjects. For example, 12 percent of the students scored distinctions in physics. Many of the students had 'e' symbols as their lowest score, and the percentages of students with 'e' symbols ranged from 6 to 26 percent.

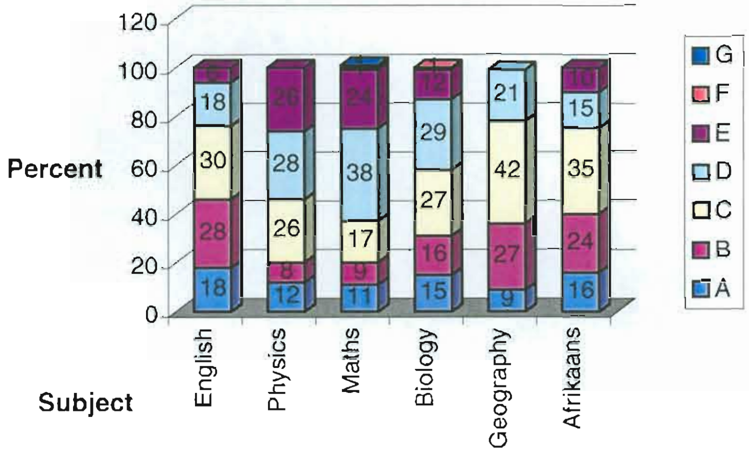

Figure 3.6. The Matric Symbol Distribution in the Sample

Seventhly, these students had to endure matric science classes of varying sizes. The class sizes of these students ranged from 5 to 150 students. The most common class size comprised 30 students for 32 percent of the students. About 32 percent of the students in the sample enjoyed matric science classes of less than 30 students. However, about 35 percent of the students had to endure class sizes of between 40 and 150 students. One would then project corresponding low matric performances for these students. Surprisingly, as mentioned above, there was a negligible percentage of under performing students.

Eighthly, another challenge that these students had to overcome was the variety of combinations of languages that were used to teach them. The majority of these students were taught in their first language (43 %). A close second for medium of instruction was English (42 %). Given that English was the first language of just 24 percent of the sample (see Figure 3.3. p.60), the exclusive use of English must have been a challenge to students whose first language was not English. A combination of English and the first language of the students were used for 11 percent of the students.

The graphical representation and accompanying narrative for each of the eight student characteristics described above were provided to help the reader to identify with the students in the sample. Now that the reader is familiar with some of the characteristics of the students in the sample, the methodology related to each critical question will be presented.

3.6. Methodology related to each Critical Question

3.6.1. Methodology related to Critical Question One

The first critical question is: What was the nature of the traditional science syllabi and teaching practices that the selected undergraduate physics students experienced at school, and how did it differ from transformational outcomes-based education in science and technology?

The first critical question is the historical and descriptive component of this thesis. There will be three distinct foci in the response to this question. First, an examination and comparison of syllabus and policy documents related to the traditional science curriculum and the new transformational science curriculum. This first segment will provide a theoretical basis to inform the understanding of the second segment, which is a descriptive discussion of the actual teaching and learning experiences of the students. And thirdly, there will be an analysis of the relationships that exist between the teaching and learning experiences of the students. The research methods used in each of these three focus areas of critical question one will be described below.

To compare the differences between the traditional science curriculum and the new transformational science curriculum, the following key features of the associated policy documents will be examined:

I. Underpinning Learning Theory;
II. Goals;
III. Objectives/Outcomes;
IV. Content;
V. Teaching Strategies/Methodologies; and
VI. Assessment Strategies.

The data sources that will be used to provide insight into the nature of the syllabus and teaching practices that the selected undergraduate science students experienced at school will include:

I. The Policy Documents:

Curriculum Model of South Africa (CUMSA) Discussion Document (DOE 1992a);
CUMSA - abbreviated with Questions and Answers (DOE 1992b)
The Education Renewal Strategy (ERS) Discussion Document (DOE 1992c)
ERS, Questions and Answers (DOE 1992d)

These policy documents profoundly informed the development of a general response to the nature of the traditional science curriculum.

II. Syllabus documents that defined the content of Science at Secondary School:

A Subject Policy for Physical Science (DOE 1993);
Syllabus for Physical Science (Higher and Standard Grade) Standards 9 and 10 (DOE 1994); and the
The Interim Core Syllabus for General Science Ordinary Grade, Standards 5, 6 and 7 (DOE 1995).

The data sources that will be used to provide insight into the nature of the syllabus and teaching practices consistent with outcomes-based education will include:

i. The Lifelong Learning for Education and Training Document (DOE 1996a);
ii. The Discussion Document of C2005 (DOE 1997a);
iii. Outcomes-Based Education in South Africa, Background Information for Educators - Draft (DOE 1997b); and
iv. Selected publications related to outcomes-based education.

As mentioned above, all these data sources will be used to compare the differences between the traditional science curriculum and the new transformational science curriculum. When comparing learning theories, the behaviouristic paradigm associated with the traditional science, and the integrated, learner-centred paradigm associated with transformational outcomes-based education will be discussed. There will also be an exposition of the different models of outcomes-based education. To compare the goals of the two paradigms of learning, the general or broad aims of science as envisioned in the Syllabus for Physical Science (DOE 1994) and the Interim Core Syllabus for General Science, Standards 5, 6 and 7 (DOE 1995) will be distilled and critiqued. For example, the different conceptions of knowledge generation, the interdependence between the students and science, and the various unsuccessful attempts at mainstreaming technology as a subject, will be discussed.

The comparison of objectives and outcomes will commence with definitions of these terms, and proceed to illustrate these concepts with a variety of examples. A description of critical and specific outcomes will also be provided and discussed relative to C2005. The comparison of the content components of the two paradigms will entail a description of the generally and vocationally oriented traditional curricula as outlined in the CUMSA Discussion Document (DOE 1992a). The deliberate preoccupation with content in the traditional science syllabus, and the challenges associated with the switch to the trilogy of knowledge, skills and values in the new transformational science curriculum will also be discussed.

When comparing teaching strategies, the influence of fundamental pedagogics on the traditional science curriculum will be discussed. This discussion will be followed by a comparison of the traditional science curriculum and outcomes-based education. Finally, the component on assessment strategies will focus on the summative nature of the traditional science curriculum with mid-year and final exams. Thereafter, the summative and formative nature of the OBE curriculum will be discussed, and the new terms associated with OBE, e.g. range statements, will be described.

As mentioned above, the discussion on the traditional and transformational OBE curriculum will serve as a backdrop for the second component of this first critical question, which is a descriptive discussion of the actual teaching and learning experiences of the students. Students will be requested to indicate how often they experienced each of the following kinds of teaching in science at matriculation level:

a) Mainly chalk and talk;
b) Use of textbooks to explain;
c) Questions and answers;
d) Problem solving;
e) Science experiments;
f) Work in small groups; and
g) Other

The frequency descriptors which students will be provided with for each of these kinds of teaching will be: always; most times; a few times; and never. A graphical and a frequency description will follow for each kind of teaching. Thereafter, the results will be discussed within the framework of the teaching paradigm that prevailed in the period of the students' experiences.

Similarly, students will be requested to indicate the extent to which each of the following learning methods were encouraged in science classes at school:

a) Memorize notes and equations;
b) Solve problems using numbers only;
c) Solve problems using concepts and principles;
d) Solve problems using numbers, concepts and principles;
e) Use your own ideas to understand new information;
f) Relate physics to real life; and
g) Other methods.

Once again, the frequency descriptors which students will be provided with for each of these kinds of learning will be: always; most times; a few times; and never. A graphical and frequency description will follow for each kind of learning. Thereafter, the results will be discussed within the framework of the learning paradigm that prevailed in the period of the students' experiences.

The third segment of critical question one, will be an analysis of the relationships that exist between the teaching and learning experiences of the students. In order to establish possible relationships between the different teaching and learning experiences of the students, the chi-square test statistic will be used. The test will compare; for example, whether a chalk and talk approach to teaching corresponds with a memorizing of notes learning experience. To verify the findings of the chi-square test statistic, another test statistic will be administered to establish whether any relationships exists between the kinds of teaching and learning experienced by the students. The test statistic will be the Pearson correlation test.

The first critical question will thus provide an overview of the theoretical underpinnings of the teaching and learning consistent with the traditional science curriculum, the actual teaching and learning experiences of the students, and an exposition on relationships that exist between the teaching and learning experiences of the students. The description of the methodology associated with the second critical question follows.

3.6.2. Methodology related to Critical Question Two

The second critical question is: What were the levels of scientific literacy in the selected cohort of undergraduate physics students?

As mentioned above, the descriptions of the research instruments and approaches subsumed many of the methodological features of critical questions two and three. Therefore, to avoid repetition, the methodological descriptions, which follow, will not be as extensive as that for critical question one.

The analysis of the scientific literacy scores both quantitatively and qualitatively will be preceded by two components to orient the reader to the analysis. The first component will be a synopsis of the nature of the scientific literacy questions, and a classification of the questions using Bloom's taxonomy of educational objectives: cognitive domain. The questions will be separated into knowledge, comprehension and application types. The use of Bloom's taxonomy is purely for the convenience of reviewing the data on scientific literacy, and Bloom's behaviourist principles have in no way been extended to this study. The second orientation component will be a rationale for testing the scientific literacy data for normality, and an overview of tests and frequency plots that were used to establish whether the data for scientific literacy were normally distributed. The Shapiro-Wilk Test will be administered to test whether the data were normally distributed. Frequency plots (the stem-and-leaf plot, the box plot and the normal probability plot) will sketch the distribution of scores to confirm whether they are normally distributed or not. The frequency plots will also be analyzed to establish the mean, median, and mode for the scientific literacy data. Thereafter, the true analysis of the scientific literacy scores will commence. To determine the levels of scientific literacy of the students, the following method will be employed:

As mentioned in the description of the questionnaire above, the test for scientific literacy comprised twenty questions that related to the conceptual knowledge of science as well the application of that knowledge in life. The number of correct responses will determine the scientific literacy category into which a student is placed. The original categories proposed were:

<8/20 = Scientifically Illiterate
9 to 12 = Mediocre Scientific Literacy
12 to15 = Good Scientific Literacy
16 to 20 = Excellent Scientific Literacy

However, a cluster analysis was then performed using the Centroid method and the clusters reflected above were adjusted for consistency with the statistically generated clusters. Therefore, the group referred to as scientifically illiterate had to be those with scores that were less than or equal to 8, and the mediocre scientifically literate students became those with scores of 9 to 11 out of 20. The last two groups, good and excellent scientific literacy remained unchanged. The statistical classification using the Centroid method therefore led to boundary changes for two of the original groups.

The distribution of students' scores for scientific literacy were as follows:

Ranges of Scores out of 20	Category	Number of Students	Percent
Less than or equal to 8	Scientifically Illiterate	13	7,6
9 to 11	Mediocre Scientific Literacy	48	28,1
12 to 15	Good Scientific Literacy	81	47,3
16 to 20	Excellent Scientific Literacy	29	17,0
		N =171	100

Table 3.3. The General Distribution of Students' Scores for Scientific Literacy

The distribution of scores will then be analyzed by further dissecting each of these categories to establish the detailed distributions of scores within each range. The category sizes, the absence of absolute scores, scores with the greatest frequency, will also be discussed, and the detailed distribution of scores will be displayed graphically.

The qualitative analysis will then follow. This will be a new dimension in the analysis of the scientific literacy levels of the students. This analysis will provide a description of patterns that emerge with regard to the nature of questions correctly answered by each of the groups. The analysis will specifically require an examination of the questions with the most, moderate and least number of correct responses by concept, theme, and discipline. A graphical representation of the distribution of correct responses will precede the narrative for each of the groups. Additionally, data derived from focus group interviews will be used to analyze students' conceptions of scientific literacy. Moreover, biographical data derived from the questionnaire will be used to establish which of the teaching and learning methods are the most influential in determining scientific literacy levels, and which factor is the best predictor of scientific literacy.

The methodology associated with the third critical question is similar and will be provided below.

3.6.3. Methodology related to Critical Question Three

The third critical question is: What were the levels of technological literacy in the selected cohort of undergraduate physics students?

Once again, it must be reiterated that many of the methodological features of the third critical question were incorporated in the discussion of the questionnaire and the SOLO taxonomy. Therefore, to avoid repetition, only those features of the methodology that were omitted above will be described below.

The actual analysis of technological literacy scores is preceded by two precursor components. First, a brief review of the nature of the technological literacy questions, followed by a table which classifies students' responses using the SOLO Taxonomy, and then a concise description of the differences between the analysis of technological literacy scores as compared to scientific literacy scores. This comparison will also focus on the ranges of scores, the means, median and modes. Second, the rationale for testing the technological literacy data for normality, and subsequent tests and frequency plots to test for normality of the data. The Shapiro-Wilk Test will be administered to test whether the data were normally distributed. Frequency plots (the stem-and-leaf plot, the box plot and the normal probability plot) will sketch the distribution of scores to confirm whether they are normally distributed or not. The frequency plots will also be analyzed to establish the mean, median, and mode for the technological literacy data.

The analysis of technological literacy scores will then proceed. First, the mean score of the technological literacy questions will be calculated for each student. The students will then be categorized using the SOLO Taxonomy as follows:

X = 1 Technologically Illiterate or Prestructural
X = 2 Unistructural Technological Literacy
X = 3 Multistructural Technological Literacy
X = 4 Relational Technological Literacy
X = 5 Extended Abstract Technological Literacy

The general and detailed distribution of technological literacy scores will then be discussed, and the caveats associated with their use will be highlighted. The discussion on the general distribution will focus on the frequency of students within each of the SOLO Taxonomy categories. The detailed distribution discussion will magnify the distribution of prestructural, unistructural and multistructural scores.

Thereafter, the technological literacy scores will be compared with scientific literacy scores for each student to establish if there were similarities in the two sets of scores. Depending on the extent of overlap, the combined categories will be used for the qualitative analysis of responses to the six questions on technological literacy.

The qualitative analysis of the six questions on technological literacy will provide a portrait of the patterns and qualitative differences in the responses of the different combined categories of students. This is a new dimension in the analysis of the technological literacy levels of the students. For each technology related question, the task and expectations will be described. Thereafter, the responses of each combined category of students will be presented separately to illustrate the quality of responses. The responses will be discussed relative to SOLO taxonomy level descriptions. Actual student responses will be used to provide a more accurate description of how students think when confronted with questions on technological literacy.

Finally, for each question a summary will be presented for all the categories of responses to compare differences, and question any anomalies which may surface in the expected progression of the quality of responses from category one through to four. For example, if category four students do not offer responses that are qualitatively superior to those in category 3, an explanation will be offered.

3.7. Summary of Data Sources

The foregoing discussions on instruments and how they are linked to critical questions or other aspects of this study are extensive and complex. To facilitate an understanding of the relationships that exist between data sources and corresponding research components, Table 3.3. below has been developed. Table 3.4. also identifies whether the data is qualitative or quantitative.

Research Component	**Data Source**	**Nature of Data**
Profile of Sample	Questionnaire, Part 3.	Quantitative
Critical Question 1	Questionnaire, Part 3.	Quantitative
Critical Question 1	Policy/Syllabus Documents, Selected Publications.	Qualitative
Critical Question 2	Questionnaire, Part 1.	Quantitative/Qualitative
Critical Question 3	Questionnaire, Part 2.	Quantitative/Qualitative
Verification of Findings from Questionnaire	Focus Group Interviews	Qualitative

Table 3.4. The Relationship between Research Components and Data Sources

3.8. Conclusion

This chapter has provided insights into the complex nature of a Mixed Methodology Design Model of combining qualitative and quantitative research methods. All three critical questions are inextricably linked to the questionnaire that serves as a fountain from which both qualitative and quantitative data springs. The journey through the description of the questionnaire showed how the different components were designed to elicit data for each critical question. The discussion on the SOLO Taxonomy and its relevance to this study introduced new avenues for the assessment of open-ended qualitative responses to questions. For example, the classification of student responses using the SOLO Taxonomy levels that range from prestructural to extended abstract types. The sample description went beyond the just providing biographical details to an exposition of, amongst others, first languages of students, medium of instruction in matric science classes at schools, and the number of students in these classrooms. All the above paved the way for the description of the research methodologies associated with each critical question, which in turn sets the scene for the forthcoming three chapters which present and analyze the data associated with each critical question.