UNIVERSITEIT VAN PRETORIA
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THE SCIENTIFIC AND TECHNOLOGICAL LITERACY OF FIRST YEAR PHYSICS STUDENTS: THE EFFECTS OF A TRADITIONAL SCHOOL CURRICULUM

by

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Submitted in partial fulfilment
of the requirements for the degree:
Philosophiae Doctor (PhD)
in the Faculty of Education, University of Pretoria.

Submitted: December 2001
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Abstract (491 words)

This study examined the scientific and technological literacy levels of a cohort of first year physics students at the University of Pretoria who experienced a traditional science school curriculum. Inspired by the concept of innovation as advocated in the White Paper on Science and Technology (Department of Arts, Culture, Science and Technology 1997), this study was informed by two innovations. The first innovation was to develop insights and methods to evaluate science and technology literacy levels of learners in South Africa that were consistent with the Outcomes–Based Education (OBE) paradigm. The second innovation was the use of the Strategic Objectives Learning Outcomes (SOLO) taxonomy to evaluate qualitative responses to questions pertaining to technological literacy as a model for addressing the lack of grade-based benchmarks against which to assess learner performance in Curriculum 2005. The study also examined the nature of the traditional science syllabi and teaching practices that the students experienced at school, and how it differed from transformational OBE in science and technology.

The literature search analyzed and traced the evolution of the concepts of scientific and technological literacy against the backdrop of an examination of the underlying concepts of science and technology. The course of this study was shaped by the Mixed Methodology Design Model of combining qualitative and quantitative research methods. The principal research instrument in this study was a questionnaire on science and technology literacy related issues. The qualitative focus of the research was evident in the use of open-ended questions in parts of the questionnaire and their subsequent analysis using the SOLO taxonomy. The quantitative focus of this research manifested itself in the statistical analyses that were administered.

A principal finding related to the nature of the traditional science curriculum was a striking disconnect between the most frequent teaching and learning experiences of the students. By and large, the most frequent teaching methods were traditional in nature. However, the most frequent learning methods were generally more progressive. The impact of the traditional curriculum was defied once again when the impressive scientific literacy levels of the students were revealed. However, the same kind of relationship did not hold true for technological literacy levels of the students which were acceptable but not as impressive as the scientific literacy scores. This differential was defended by the literature, as technology education does not have a structured body of knowledge, concepts, principles, and ideas that define an academic discipline. Therefore, it follows that there is no valid way of determining curriculum content. Hence, the researcher concluded that what was measured may be more accurately described as intuitive technological literacy.

The success of the innovations used in this study has two main implications. First, we can measure scientific and technological literacy levels of the nation and use the results to develop a strategy for scientific and technological advancement. Second, in terms of curriculum transformation, the SOLO taxonomy is a viable and simple method of facilitating learner performance reviews and learner progression.

10 key words:

Science, Technology, Scientific Literacy, Technological Literacy, Outcomes-Based Education, Curriculum 2005, SOLO taxonomy, Mixed Methodology Design Model, Traditional, Transformational.

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Chapter One
Introduction

1.1. Orientation to the Chapter

This chapter provides an orientation to this study on the scientific and technological literacy levels of first year physics students, and the effects of a traditional school curriculum. The chapter commences with a discussion of the rationale and background that informed this study. Thereafter, the purpose and critical questions of this study are presented. This is followed by a brief description of the methodologies embraced in the pursuit of the critical questions, an outline of the literature review, and a preview to forthcoming chapters.

1.2. Rationale and Background

The South African White Paper on Science and Technology, hereafter the White Paper, which was commissioned by the Department of Arts, Culture, Science and Technology (DACST) is shaped by "the twin concepts of innovation and a national system of innovation" (DACST 1997:4).

The concept of innovation is defined as "the application of creative new ideas…" (ibid:12). Creativity, in contrast to innovation, is perceived within the White Paper as the generation and articulation of new ideas. Accordingly, innovation entails taking creative ideas, even those that originated elsewhere, and winning acceptance for them, putting them to use, or exploiting them by turning ideas into products and services that other people will buy and use.

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. If the insights and methods developed in this study are taken to scale in South Africa, it could facilitate the assessment of scientific and technological literacy levels of learners, which could then inform methods to enhance those levels.

The White Paper goes on to endorse "the improvement of well–being of individuals through their acquiring skills to deal with the day-to-day challenges of society" (DACST 1997:47). Within this framework of developing human resources, "new approaches to education and training need to be developed... (which) require new curricula and training programs that are comprehensive, holistic and flexible..." (ibid:9). The new curricula and training programs need to resonate with the concept of lifelong learning that also permeates the White Papcr. Lifelong learning is holistic and integrated in that it combines the socio-economic needs of the country and the development needs of an individual. The South African Department of Education (DOE) has embraced a lifelong learning approach to education and training in the form of OBE since 1998.

OBE is a "learner centred, results oriented system in which a learner's progress is based on demonstrated achievement of a predetermined outcome" (Unofficial document of the DOE 1996, cited in Goolam 1997:1). "Outcomes are what learners can actually do with what they know and have learned – they are the tangible application of what has been learned. This means that outcomes are actions and performances that embody and reflect learner competence in using content, information, ideas, and tools successfully" (Spady 1994:2).

OBE provided the framework for the new curriculum in South Africa, namely Curriculum 2005 (C2005). C2005 was sequentially introduced into the schooling system in South Africa starting with Grade One in 1998 and the entire system was expected to be OBE compatible by 2005. Hence, the label C2005. Of course, the South African interpretation of OBE adds nuances to the concept that make it more meaningful locally. For example, some of the critical outcomes of C2005 resonate strongly with the Constitution of South Africa. The critical outcomes proposed in the Discussion Document of C2005 seek to enable learners to:

1. *Identify and solve problems and make decisions using critical and creative thinking;*
2. *Work effectively with others as members of a team, group, organization and community;*
3. *Organize and manage themselves and their activities responsibly and effectively;*
4. *Collect, analyze, organize and critically evaluate information;*
5. *Communicate effectively using visual, symbolic and/or language skills in various modes;*

6. *Use science and technology effectively and critically showing responsibility towards the environment and health of others; 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*

(DOE 1997a:10).

Critical outcomes 1; 4; 6 and 7, lend themselves directly to this study and the demonstration of specific outcomes in science and technology that are subsumed within critical outcome 6 will be explored in depth in this study.

C2005 also embraced developmental outcomes that contribute to the personal developmental of the learner as well as the social and economic development of society. According to the Discussion Document of C2005, the five developmental outcomes include:

1. *Reflecting on and exploring a variety of strategies to learn effectively;*
2. *Participating as responsible citizens in the life of local, national and global communities;*
3. *Being culturally and aesthetically sensitive across a range of social contexts;*
4. *Exploring education and career opportunities; and*
5. *Developing entrepreneurial abilities*

(ibid:10-11).

The demonstration of the developmental outcomes by students will not be explicitly evaluated in this study. However, developmental outcomes 2 and 3 resonate well with critical outcome 6 that is directly related to this study. Hence, there will be an implicit evaluation of developmental outcomes 2 and 3. Chisholm et al (2001a) have retained the same critical and development outcomes discussed above in the Draft Revised National Curriculum Statement[1] (NCS) for Grades R-9. The NCS represents an attempt to strengthen and consolidate C2005. As mentioned above, these twelve outcomes are derived from the Constitution of South Africa, and "they describe the kind of citizen the education and training system should aim to produce" (Chisholm et al 2001a:16).

[1] The Draft Revised National Curriculum Statement for Grades R-9 was produced after this study was submitted for examination, and its reference in this updated version of this study is to demonstrate the continuity of the concept of critical and development outcomes in the revision of C2005.

C2005 represented a quantum leap for education in South Africa as it necessitated a paradigm shift for the nature of teaching and learning. The typical focus on curriculum inputs (content) was displaced by curriculum outputs (results). The implementation of C2005 necessitated corresponding changes in teaching methodologies. According to the Lifelong Learning for Education and Training Document, teaching methodology will be characterized by:

- *"Change in the perception of educators from dispensers of knowledge to active participants or guides on the side or facilitators of learning;*
- *Activity based learning where learners explore ideas and approaches to learning and practice skills;*
- *Co-operative as well as individual learning contexts so that learners can develop skills of working collaboratively in a group, and individually, and the ability to recognise when each mode is appropriate;*
- *Formative assessment, so that the processes and developmental nature of learning, as well as products are seen as important;*
- *The setting of tasks that integrate theory and practice, and manual and mental learning where practicable, and which link classroom learning to the broader society in which it is located"*

(DOE 1996a:46).

In essence, the exclusive emphasis on knowing, as was customary in the past, is now supposed to be displaced by the demonstrated application of the knowledge, skills and/or values. Moreover, the shift to OBE requires a formative approach to assessment, as teachers must assess learners' progress continually. However, assessment of the demonstrated application of the knowledge, skills and/or values has been contentious since the inception of C2005. There are several reasons for the debate on assessment, and just two of them will be provided here. First, according to Chisholm et al (2000:62), who produced the Report of the Review Committee on C2005, "a comprehensive assessment policy did not accompany C2005 in its first year of implementation" Second, even when a National Assessment Policy was developed in 1998, there were some conspicuous gaps. One of the gaps identified in the Centre for Education Policy Development (CEPD) submission to the Review Committee on C2005 pertained to the lack of grade-based benchmarks against which to assess learner performance. Part of the reason for the latter, which was provided in the Discussion Document of C2005, is because "the assessment criteria are broadly stated and do not themselves provide sufficient details of exactly what and how much learning marks an acceptable level of achievement of the outcome" (DOE 1997a:12).

The second innovation in this study is to introduce the Strategic Objectives Learning Outcomes (SOLO) Taxonomy to compensate for the gaps identified in the National Assessment Policy of 1998 pertaining to grade-based benchmarks against which to assess learner performance.

The SOLO Taxonomy is a systematic way of describing how we arrive at our qualitative judgments when reviewing learner responses. Killen (2000) argues that the SOLO taxonomy is one system that can be used to provide more useful feedback to learners. The SOLO taxonomy will be used specifically to evaluate the technological literacy levels of the cohort of physics students. There are significant implications for C2005 in South Africa if the SOLO Taxonomy emerges as a viable option to assess qualitative outcomes when reviewing learner responses. It will provide South Africa with a simple, yet systematic, method of facilitating learner performance reviews and learner progression.

In this study, both the scientific and technological literacy levels of the students will be evaluated against the transformational specific outcomes for science and technology. It is speculated that transformational outcomes for science and technology can be demonstrated by these students although they are products of traditional syllabi and teaching methods. This speculation is premised on the very nature of science and technology, both of which are OBE oriented.

For example,

> *"the purpose behind a scientific activity is to build knowledge: to build up an explanation for something; to provide a true description of some event; (and) to diagnose the nature of some condition. The purpose behind a technological activity is to facilitate a human aspiration; to solve some practical problem; to put knowledge to good use; to extend the boundaries of existing possibilities"*
>
> (UNESCO 1982:16).

Science and technology, if true to the above descriptions, can manifest themselves in the demonstration of critical outcomes as envisioned by the policy documents regardless of whether traditional or OBE curricula were pursued.

1.3. The Purpose of this Study

This study will examine whether a selected cohort of undergraduate physics students at the University of Pretoria who experienced traditional science syllabi and teaching methods at school can use science and technology critically and effectively showing responsibility towards the environment and health of others (see critical outcome 6 above). The application of scientific and technological literacy through the demonstration of associated outcomes in everyday life situations will be used as a barometer of scientific and technological competence.

Within the framework of this broad purpose, the research will address the following critical questions:

1.3.1. 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?

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

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

Each of these critical questions will be explored using the research methodologies described below. Before this description is provided, a brief rationale for each of the critical questions follows. Rather than make assumptions about the effects of the traditional curriculum on the science syllabi and on teaching and learning practices, the first eritical 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).

1.4. Research Methodology

The research methodology of this study can be described best as the "mixed methodology design model" (Creswell 1994, cited in De Vos 1998:361) of combining qualitative and quantitative research. The mixed methodology method entails mixing "aspects of the qualitative and quantitative paradigm at all or many methodological steps in the design" (ibid). The quantitative focus of this study manifests itself in various ways. For example, the numerical calculations associated with the scientific and technological literacy levels of the subjects. The qualitative focus of the research is evident, amongst others, in the use of open-ended questions in the questionnaire to elicit qualitative responses from the students.

The target population in this study will be the cohort of physics undergraduate students at the University of Pretoria in their first year of study in 2000. From this population a sample of convenience will be engaged based on availability and willingness of students to participate in the study. The sample will be fully representative of the population of first year, physics undergraduate students at the University of Pretoria. The major instrument that will be used to collect data on scientific and technological literacy, and biographical data of students, will be a questionnaire. Focus group interviews will also be conducted to corroborate some distillations from the questionnaire, and to compare conceptions of scientific and technological literacy from the literature with those of students.

For each critical question there will be a mutually exclusive methodology. The first critical question reflects the historical and descriptive component of this thesis. There will be two distinct components to this question. The first component will be a theoretical comparison of the differences between the traditional science curriculum and the new transformational OBE seience curriculum. The second component will explore the actual teaching and learning experiences of the physics students when they were at school.

The second critical question will entail a quantitative analysis of the results of the scientific literacy test to separate students into the following scientific literacy categories: Scientifically Illiterate, Mediocre Scientific Literacy, Good Scientific Literacy, Excellent Scientific Literacy. Thereafter, the questions with the most, moderate and least number of correct responses in each category will be examined to identify concepts, themes, disciplines that are most popular for each scientific literacy category.

For the third critical question, the qualitative responses to the questions on technological literacy will first be classified using the SOLO Taxonomy. In order of increasing complexity the SOLO Taxonomy levels are prestructural, unistructural, multistructural, relational, and extended abstract. Prestructural responses are incorrect, inadequate or irrelevant while unistructural responses provide one aspect of correct data, multistructural responses provide many aspects of correct data incoherently, relational responses are similar to multistructural responses but they link the data coherently, and in extended abstract responses the learner engages abstract features representing a higher mode of operation. The responses within each category will then be analyzed to establish whether corresponding SOLO Taxonomy characteristics are exhibited and this analysis will be used to provide a portrait of the patterns and qualitative differences in the responses. The results will demonstrate whether the SOLO Taxonomy is a viable option for enhancing the assessment of qualitative outcomes in the implementation of OBE in South Africa.

1.5. Literature Review

A literature review can be conceived parochially and feature as an insulated component of a thesis. Alternatively, references to literature can pierce and punctuate the text for corroboration and embellishment. The latter approach to a literature review has been pursued deliberately in the foregoing text with references to:

The White Paper on Science and Technology (DACST 1997); the Discussion Document of C2005 (DOE 1997a); the Lifelong Learning for Education and Training Document (DOE 1996a); a UNESCO publication (1982); Killen (2000); an unofficial document of the DOE 1996, cited in Goolam 1997; Chisholm et al (2000); Chisholm et al (2001a); the Laugksch Study (1994); and a book by William Spady (1994).

What follows are complementary references to literature sources in an attempt to paint a picture, in broad brushstrokes, of the science and technology literature review that will inform this study. The literature review component will analyze and trace the evolution of the concepts of scientific and technological literacy. The literature will also differentiate between science and technology and formulate operational definitions for such terms to facilitate this study. After discussing the two concepts of science and technology, the review will examine a wide range of perspectives of the two concepts of scientific and technological literacy; and then explain the necessity for scientific and technological literacy.

This differentiation between the two underlying concepts of science and technology is important because, according to the White Paper (DACST 1997) there is considerable debate as to whether technology is a discipline in its own right, whether it should be taught as part of science, or spread across the curriculum. Confusion also reigns as to the philosophical underpinnings of technology and these need to be clarified as well.

Ntshingila-Khosa (1998) contends that science and technology are not identical. They are interdependent but contrasting activities. The role of science is to enlighten humanity. The role of technology is to use the existing knowledge to serve humanity. Herschbach (1995, cited in Ntshingila-Khosa 1998:1) traced the etymology of the word technology as being 'reasoned application', a reasoned application of technological knowledge. Herschbach's (1995) conception of the word technology can be confusing as knowledge is generated by science not technology, as reverberated in the Ntshingila-Khosa (1998) argument above.

The confusion that reigns about science and technology, or the fact that they are often equated could be attributed to the fact that "it is quite common for people to talk about 'science and technology' as if it was one thing with a double-barrelled name" (Sparkes 1996:25). The same author attributes this apparent haziness between science and technology to common features, which the two terms share, but more importantly because of neglect and the repeated use of the term science and technology.

For the purposes of this study, technology will be considered as applied science in the context of daily life practices. This study embraces the Brookes et al (1994:104) conception of technology as "the study of how to manipulate or organize the environment to enable people to do what they need and want to do." This interpretation presupposes that a body of knowledge is an essential prerequisite to successfully manipulate and organize the environment. However, the translation of the theory into successful manipulation or organization of the environment is not necessarily spontaneous. This study will examine the extent to which the body of knowledge or scientific literacy is applied successfully in everyday life.

1.6. Orientation to Forthcoming Chapters

Chapter two will analyze and trace the evolution of the concepts of scientific literacy and technological literacy. The two root concepts of science and technology will first be examined before an assortment of conceptions of scientific literacy and technological literacy is presented. There will be a deliberate attempt to define scientific literacy and technological literacy in the context of this study. The chapter will conclude with a discussion on the necessity for scientific and technological literacy.

Chapter three will provide a narrative of the research processes engaged and then proceed to describe sampling procedures, specific research instruments, and approaches explored. Research instruments will include a questionnaire and an interview schedule. Research approaches will entail the use of qualitative strategies like the SOLO Taxonomy.

Chapter four will address the first critical question of this thesis. It will commence with a pithy examination and comparison of syllabus and policy documents related to traditional and OBE paradigms of teaching and learning. Thereafter, based on data from the questionnaire, a descriptive discussion of the kinds of teaching and learning experiences of the students will be presented. And finally, an analysis will be presented of relationships that exist between the different kinds of teaching and learning experiences of the students.

Chapter five will address the second critical question of this thesis; therefore, its principal focus will be on the analysis of the results of the scientific literacy test completed by the selected students. This analysis will be preceded by two precursor components. First, a preview to the data analysis to highlight factors that will inform the analysis of scientific literacy scores, e.g. the distribution of scientific literacy scores. Second, a tests and plots component to establish whether the scientific literacy scores of the selected students are normally distributed. Thereafter, the students will be separated into the scientific literacy categories as described above and examined to identify concepts, themes, disciplines that are most popular for each scientific literacy category.

Chapter six will address the third critical question of this thesis; therefore, its primary focus will be on the analysis of the results of the technological literacy test completed by the selected students. This analysis will be preceded by two quantitative precursor components. First, a preview to the data analysis component to highlight factors that will inform the analysis of technological literacy scores, e.g. a brief description of the differences between the analysis of technological literacy scores as compared to scientific literacy scores. Second, a tests and plots component to establish whether the technological literacy scores of the selected students are normally distributed. As mentioned above, the qualitative responses to the questions on technological literacy will first be classified using the SOLO Taxonomy. Thereafter, the responses within each category will be analyzed to establish whether corresponding SOLO Taxonomy characteristics are exhibited and this analysis will be used to provide a portrait of the patterns and qualitative differences in the responses.

Chapter seven, the concluding chapter, will attempt to distill the core findings related to each of the critical questions. Additionally, the core findings will be discussed, and either corroborated or contested based on what the literature states, what the statistical data analysis suggests or what emerged from the focus group interviews. Recommendations related to the core findings of this study will then be provided. Some recommendations related to the limitations of this study will also be discussed. One of the principal focuses of the recommendations will be on the potential of the SOLO Taxonomy to enhance the assessment of qualitative responses of students.

1.7. Conclusion

South Africa is a fledgling democracy and needs to assert itself on many fronts. This study affords us an opportunity to explore developments in the spheres of scientific and technological advancement, and in curriculum transformation. With regard to the former, my thesis is that to progress scientifically and technologically, we need to assess where we are and use that result as a basis of making improvements. If the methods used in this study to measure scientific and technological literacy levels prove successful, we can embrace them, assess abilities and devise methods of improvement. With regard to curriculum transformation, we are in the throes of reforming C2005, and if the SOLO taxonomy proves successful in this study, it could provide South Africa with a simple, yet systematic, method of facilitating learner performance reviews and learner progression.

Chapter Two

Literature Review

The Theoretical Underpinnings of Scientific and Technological Literacy

2.1. Orientation to the Chapter

There are a variety of conceptions as to what constitutes scientific and technological literacy. The assortment of conceptions of the two concepts will be unveiled in this literature review. Specifically, this chapter will analyze and trace the evolution of the assortment of conceptions of scientific and technological literacy. Further, it will attempt to accentuate the differences between the two concepts where possible. This chapter will commence with an examination of the underlying concepts of science and technology; proceed to discuss a wide range of perspectives of the two concepts of scientific and technological literacy; and then explain the necessity for scientific and technological literacy. The concepts of scientific and technological literacy will be discussed together as they are inextricably linked. However, there will be a deliberate attempt to define each of these two concepts relative to this study.

2.2. An examination of the underlying concepts of Science and Technology

As mentioned above, in attempting to explore some of the assortment of conceptions of scientific and technological literacy, the underlying concepts of science and technology will be examined. Indeed, a great deal of confusion reigns about scientific and technological literacy and this stems largely from the confusion that exists about science and technology. Sparkes (1996) asserts that science and technology are often equated, and this could be attributed to the fact that it is quite common for people to talk about science and technology as if it was one thing with a double-barreled name. The same author attributes this apparent haziness between science and technology to common features that the two terms share, but more importantly because of neglect and the repeated use of the term science and technology.

The equating of science and technology is a universal trend. In South Africa, we have been swaying between making a clear distinction and conflating the two disciplines for the past six years. There were two distinct factions prior to the election of a democratic government in 1994. One of the groups wanted to confer subject or learning area status on each of the two entities while the other group, Kahn (1994), advocated for the two entities to be combined. With the advent of the outcomes-based curriculum paradigm (C2005) in 1997, the government accorded technology the status of a learning area. However, Chisholm et al (2000) recommended that technology be subsumed under the umbrella of science once again. Unfortunately, the Minister of Education, together with the Council of Education Ministers and Cabinet, declined to incorporate technology under science (Potenza 2000).

The recommendation by Chisholm et al (2000) resonates with a finding of UNESCO (1983) where science and technology tended to be paired in the literature to such an extent as to imply some indissoluble bond between them, as though they connoted a single entity. The way in which UNESCO (1983) distinguishes between science and technology is to separate out the purposes of the two activities.

"The purpose behind a scientific activity is to build up knowledge: to give an explanation for something; to provide a true description of some event, to diagnose the nature of some condition. The purpose behind a technological activity is to facilitate human aspiration: to solve some practical problem; to put knowledge to good use, to extend the boundaries of existing possibilities" (UNESCO 1983:17). For example, the explanation of how an electrical circuit functions is a scientific activity but the use of such information to design a two-way switch is a technological activity.

Stahl (1994:44), similar to UNESCO (1983), maintains that "technology addresses the desire for devices in the production of commercial products and appliances. It is much influenced by human demand but is also highly susceptible to the power of capital... On the other hand, science addresses the endless human quest for knowledge of self and the surroundings... Science serves our intellectual needs, not our material needs. In contrast to technology, the pursuit of science depends entirely on altruism through public and private resources. Any so called "pay-off"- other than pure knowledge – involves a conversion into technology, the passage from idea to device or product."

UNESCO (1983:18) contends that "science and technology are not identical. They are interdependent but contrasting activities. The role of science is to enlighten humanity. The role of technology is to use the existing knowledge to serve humanity."

Herschbach (1995, cited in Ntshingila-Khosa 1998:1) traced the etymology of the word technology as being 'reasoned application', a reasoned application of technological knowledge. There is a distinct difference between the Herschbach (1995) interpretation of the word technology and that proposed by UNESCO (1983) presented above. The latter contends that it is science that generates knowledge, and that technology is the application of that knowledge. Thus, the use of the concept technological knowledge by Herschbasch (1995) becomes confusing when trying to dissect out the differences between science and technology. Nonetheless, the concept of technological knowledge became more meaningful when the author traced the evolution of the word technology. The earliest conceptions of technology placed emphasis on conceptual material, e.g. understandings, knowledge, decision making, etc. This early conception of technology blends in with the Herschbach (1995) understanding of the word technology. An elaborated discussion on the early conceptions of technological literacy features below (see sub-section 2.3.4. pp.34-40).

Brookes et al (1994) took the Herschbach (1995) concept of reasoned application one step further. Brookes et al (1994) envisioned technology as the study of how to manipulate or organize the environment to enable people to do what they need and want to do. This interpretation intimates that a set of experiences or a body of knowledge is necessary to manipulate and organize the environment. However, the translation of the theory into successful manipulation or organization of the environment is not necessarily spontaneous. This study will examine the extent to which the body of knowledge or scientific literacy is applied successfully in everyday life.

The Brookes et al (1994) definition begs a further question that was pursued by Naughton (1990). The latter enquired whether technology is necessarily the application of scientific knowledge because he believed that technology did not necessarily involve the exclusive application of scientific knowledge. For example, it is common sense that the design of a car requires scientific data like aerodynamics. However, the task cannot be accomplished without other kinds of knowledge as well. These other kinds of knowledge include how the driver feels about driving the car, and how the driver responds to the car's appearance. Thus, other kinds of knowledge like experience, craft knowledge and feelings about a particular product are also vital to the technologists. In short, science is not the exclusive factor in technological design.

Naughton (1990:9) accordingly defined technology as the "the application of scientific and other knowledge to practical tasks by organizations that involve people and machines." The element of practicality in Naughton's definition stems from addressing real life situations. The "other knowledge" has been explained above. The use of the words people and machines in the definition is because technology is a complex interaction between people and social structures on the one hand, and machines on the other.

Yet another dimension of technology is manifested in its interpretation as process. In the United Kingdom (UK), technology was introduced as a compulsory component of the education of all children within the state system (Shield 1996, cited in Ntshingila-Khosa 1998). This approach was intended to improve the competitiveness of the nation but its rationale has been questioned by Custer (1995, cited in Ntshingila-Khosa 1998) as he describes the UK government's intervention as a partial understanding of a complex subject. Shield (1996, cited in Ntshingila-Khosa 1998) adds that insufficient attention has been given to technology as doing as well as understanding. In South Africa, we had a similar initiative to the UK in that the Technology 2005[2] (T2005) team, which subscribed to the conception of technology as a problem-solving process (see Rogan et al 1998:10, T2005, National Evaluation Study, Gauteng Province Final Report), and designed technology materials for Grade I learners. However, Reddy (1998) argues that this integration of technology into the life-skills curriculum could lead to technology being sidelined or diluted. While materials were designed by the National T2005 team, the members of the T2005 Gauteng Task Team (GTT) are very explicit that technology cannot be narrowly defined vis-à-vis' life-skills nor technical subjects like woodwork. This broader conception of technology implicit in the GTT interpretation creates the impression that technology is a complex concept like curriculum, and cannot be defined by one of its features, like syllabus is oftentimes incorrectly used to define curriculum.

The above review of the underlying concepts of science and technology was intended to create a backdrop to an examination of the perspectives of the concepts scientific and technological literacy which will now be elaborated upon.

[2] The Draft National Framework for Technology 2005 (DOE 1996b) defined the T2005 project as a three-year curriculum development program that aimed to develop:

- a National Curriculum Framework for Technology Education in the compulsory school phases;
- appropriate pre- and in-service Teacher Education programs in technology education for compulsory phase teachers; and
- systems for implementation and evaluation of the Technology 2005 project in the participating provinces.

According to Reddy (1998), the initial role of the T2005 team was to explore the feasibility of implementing T2005, but it has developed into a curriculum development and training project.

2.3. The Evolution of the concepts of Scientific and Technological Literacy

In the perspectives on scientific and technological literacy that follow there is widespread acceptance that a variety of interpretations of the two concepts co-exist. Also glaringly evident in the literature, is the evolution of the concepts from rather basic interpretations of lexical knowledge of science, to sophisticated and comprehensive versions of the two concepts. For example, the concept of scientific literacy has evolved through phases of practical literacy and civic literacy Shen (1975, cited in Shamos 1995), cultural literacy (Hirsch 1997, cited in Zuzovsky 1997) and functional literacy, and then to a multidimensional construct (Eisenhart, Finkel and Marion 1996, cited in Bybee 1997). After reviewing the literature on the two concepts of scientific literacy and technological literacy, it is the author's best understanding that the concept of scientific literacy spawned that of technological literacy. Thus, in early times (1930s to 1970s) the concept of scientific literacy predominated. Thereafter, the concept of technological literacy was almost implicit in scientific literacy and only later on (1980s) did technological literacy acquire independent status, although the two terms are still used interchangeably as are the concepts of science and technology.

Each of the variations of the concepts of scientific and technological literacy will be discussed below. Moreover, in the following summary of perspectives on scientific literacy, the viewpoints of different academics (Shamos 1995; Charp 1996 & 1999; Fensham 1995 & 1999; Baarah & Volk 1994; Doke 1998; Bauer 1992; Bybee 1995 & 1997; DeBoer 1999; Jenkins 1999; De Vos and Reiding 1999; Laugksch 2000; Kolstoe 2000; Eilks 2000; Parkinson 1999; Cross & Price 1999; Hand et al 1999; and Hanharan 1999) are juxtaposed within the framework of a core set of ideas of the two concepts presented by Zuzovsky (1997). The latter was by far one of the most coherent presentations of the evolution of the two concepts.

Zuzovsky (1997:232) asserts that "scientific and technological literacy remain vague terms which are defined and interpreted in many different ways. Early definitions refer mostly to the ability of individuals to read about, comprehend and express an opinion on scientific and technological matters." Zuzovsky (1997) provides a comprehensive analysis of the two concepts from the 30s through to the 2nd World War and then in the 80s and 90s. An abbreviated version of the chronological analysis of Zuzovsky (1997) follows. Each of these phases of evolution of the two concepts as perceived by Zuzovsky (1997) will be embellished with the perspectives of other writers as well as those of the author.

2.3.1. Scientific Literacy in the 30s

Zuzovsky (1997:232) contends that "during the 30s, scientific literacy was conceived as the unique contribution of science to general education, a tool for developing desirable thinking habits such as open-mindedness, intellectual integrity, observation and interest in testing one's own opinions (Dewey, 1934)." The author's first reaction to this early interpretation of scientific literacy was that it was characterized by a distinct element of generality, with a focus on non-science specific (general) knowledge and an overwhelming silence on the use of scientific knowledge in society. However, Shamos (1995) disproves the author's assertion as he states that Dewey believed that high school science education should accomplish more than merely prepare the student in a practical way for eventually playing a useful role in society. In fact, because of the influence of writers like Dewey in the twentieth century, science education "was justified more and more on the basis of its relevance to contemporary life and its contribution to a shared understanding of the world on the part of all members of society" (DeBoer 1999:583).

Bybee (1997) also provided a chronological overview of the concept of scientific literacy but differs with Zuzovsky (1997) in that Bybee's (1997) research concluded that Conant first used the term scientific literacy in 1952. Bybee (1997) adds that Conant (1952) used the term scientific literacy to denote a broad understanding of science. It is apparent that other writers, like DeBoer (1999) and Laugksch (2000), concur with the 1950's origin of the term scientific literacy. DeBoer (1999:582) states quite explicitly that "scientific literacy is a term that has been used since the late 1950s to describe a desired familiarity with science on the part of the general public." Laugkscb (2000:72) adds that "the term scientific literacy was coined in the 1950s."

It is important at this juncture to note that the concept of scientific literacy may also be defined as public understanding of science, as intimated in the latter part of DeBoer's (1999) statement above. Other labels that are used synonymously with scientific literacy include "citizen science" (Jenkins 1999:704). Laugksch (2000) used a geographical basis to separate the different labels of the concept because the term scientific literacy is more common in the United States, while public understanding of science is more widespread in Britain (and other parts of Europe), and another way of describing scientific literacy is "la culture scientifique," which is a term used in France.

Regardless of when the term scientific literacy was first used, it is clear that early interpretations are fingerprinted by simplistic interpretations of scientific literacy. These early interpretations embrace a factual knowledge of science, which is used to develop what Shamos (1995) referred to as scientific habits of mind or scientific attitude, which is a rational or logical way of thinking that is supposed to be an outcome of being a scientist. Incidentally, Shamos (1995) and Miller (1983, cited in Shamos 1995) believed that the concept of scientific attitude, which was developed by Dewey, triggered the scientific literacy movement.

With the outbreak of the Second World War in 1939, there was a lull in the refinement of the concept of scientific literacy. In fact, only in the 1950s was the concept of scientific literacy resurrected and revisited as discussed below.

2.3.2. <u>Scientific Literacy after the 2nd World War</u>

Zuzovsky (1997:232) asserts that "after the 2nd World War, there was a demand for knowledge that would enable citizens to become more aware of science-related issues, so that in a democratic society, they would have the power to affect public and technological policy. This demand often referred to as 'civic literacy' was defined by Benjamin Shen (1975)." Shen (1975, cited in Shamos 1995) referred to the civic literacy as the last cornerstone of informed public policy. Shen (1975, cited in Shamos 1995) believed that the aim of scientific literacy is to enable the citizen to become more aware of science and science-related issues so that he and his representatives can bring their common sense to bear upon these issues. Interestingly, this concept of civic literacy seems to have gained momentum again in the 1990s through the concept of "citizen science, i.e. science which relates in reflexive ways to the concerns, interests, and activities of citizens as they go about their everyday business" (Jenkins 1999:704).

As mentioned above, Bybee (1997) insisted that Conant was the first to use the concept of scientific literacy in 1952. Bybee (1997) adds that in the early 1950s, the term scientific literacy was often associated with discussions of general education in science. Bybee (1997) states that Hurd was the first person to use the term scientific literacy as a major theme for science education in 1958. The Hurd interpretation of scientific literacy was an understanding of science and its applications to social experience, and science was integral to economic, political and personal issues. It is imperative to understand the context within which this resurgence in the interest in scientific literacy emerged in 1958. In 1957, the Russians launched Sputnik, the first ever earth satellite, and this caused much embarrassment for the Americans and compelled them to reform their curriculum. The reform of the curriculum in America entailed a strong, cognitive centered curriculum with science being a core subject to cultivate the mind. The American President's Commission on National Goals (1960) "gave top priority to science, mathematics..." (Ornstein & Hunkins 1988:156) and the focus on subject matter was supported by legislation to provide training and resources in the associated subjects.

The 1960s can best be described as the era of sloganeering in the evolution of the concept of scientific literacy as the concept tended to be used as a major educational aim (Roberts 1983, cited in Bybee 1997). Among those cited as using scientific literacy as a slogan are Fitzpatrick (Policies for Education 1960), Kusch (Education for Scientific Literacy in Physics 1960), Johnson (The Goals of Science Education 1962), and Wittlin (Scientific Literacy in the Elementary School 1963) [Bybee 1997]. Other interesting developments in the 1960s provided by Bybee (1997) included Hurd's (1963) definition, which emphasized the knowledge of key science concepts, relating these concepts in a coherent way, the social relevance of science, and the limitations of science. Another interpretation of scientific literacy emerged from Koelsche (1963, cited in Bybee 1997) who viewed the concept as the knowledge and skills required to read and understand science as presented in the media. Also, Shamos (1963, cited in Bybee 1997) characterized scientific literacy in the 1960s as knowing science in a humanistic way or feeling comfortable in reading or talking with others about science in a non-technical way. Interestingly, in subsequent articles, Shamos asserted that scientific literacy is essentially unachievable for most people (see sub-section 2.3.3. pp.21-34). Laugksch (2000) contends that in 1962, Snow made a contribution to the development of the term scientific literacy. The author finds it difficult to accept Snow's contribution because Snow drew a distinction between literary intellectuals and scientists, and did not really attempt to define scientific literacy.

Bybee (1997) also provided details on a very significant scientific literacy development in the mid-1960s. Bybee (1997) cites the Pella, O'Hearn and Gale (1966) study that examined one hundred articles to determine what science educators meant by the term scientific literacy. They reported the six most frequent referents:

1. interrelations between science and society; 2. ethics of science; 3. nature of science;
4. conceptual knowledge; 5. science and technology; and 6. science in the humanities.

They found that the primary purposes of scientific literacy were to prepare scientists, to provide the background for careers in technical occupations, and to provide general education science background for effective citizenship. They concluded that the greatest emphasis in science education should be on the latter of the three purposes of scientific literacy. Pella (1967, cited in Bybee 1997) then went ahead and defined scientific literacy using the referents listed above. This was the last development in the evolution of the concept of scientific literacy in the 1960s.

In the 1970s, following on the Pella et al studies (1966, cited in Bybee 1997), "scientific literacy, as the relationship between science and society, gained additional prominence when the National Science Teachers Association (NSTA) identified it as the most important goal of science education…" DeBoer (1999:588). The NSTA defined a scientifically literate person as "one who uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and his environment, and understands the interrelationships between science, technology and other facets of society, including social and economic development…The aim of a science-technology-society curriculum was to give students knowledge about the science/society interface and the ability to make decisions about science-related science issues" (ibid).

According to Bybee (1997), there were three more significant developments in the evolution of the concept of scientific literacy in the 1970s. These contributions were made by Agin (1974), Showalter (1974) and Shen (1975). Agin (1974, cited in Bybee 1997) published a framework for scientific literacy based on a review of the literature. He proposed six broad categories – science and society, the ethics of science, the nature of science, the concepts of science, science and technology, and science and the humanities – to aid in planning interdisciplinary teaching units, describing each and providing examples of topics and units. Showalter (1974, cited in Bybee 1997) took the process one step further and proposed seven dimensions on scientific literacy – the nature of science, concepts in science, processes of science, values of science, science and society, interest in science, and the skills of science. Showalter and his colleagues believed that these dimensions represented a continuum along which individuals progressed. Hurd also made two appearances in the 1970s with his concept of scientific enlightenment (1970), a new term for scientific literacy, and with his vision for Science, Technology and Society as well as an interdisciplinary emphasis (1975). The works of Shen (1975, cited in Shamos 1995) are elaborated below, as his conceptions of scientific literacy are the predecessors of conceptions of scientific literacy that emerged in the 1980s.

2.3.3. Scientific Literacy in the 80s and 90s

Zuzovsky (1997) goes on to discuss the change in the 80s and 90s in the goals of science education from focusing on the preparation of elite future scientists to the preparation of users and appliers of scientific knowledge, and how this led to a new type of scientific and technological literacy: cultural literacy. This component of the chapter will examine the following concepts: cultural literacy, functional literacy, Branscomb's interpretation of scientific literacy, true scientific literacy, the Project Synthesis definition of scientific literacy, and various interpretations of multidimensional scientific literacy.

As mentioned above, Shen (1975, cited in Shamos 1995) engineered the concept of civic scientific literacy. He also developed a precursor concept to that of civic and cultural scientific literacy, namely practical scientific literacy. According to Bybee (1997), practical scientific literacy included the kind of scientific and technical knowledge that can immediately be put to use to help to solve practical problems. Laugksch (2000:77) cites Shen (1975) and adds that practical scientific literacy is "knowledge that addresses the most basic human needs related to food, health and shelter."

Cultural literacy envisioned a grasp of "basic information needed to thrive in the modern world" (Zuzovsky 1997:232), something that was then translated into possession of a lexicon of scientific terms. Laugksch (2000:80) cites Hirsch (1987) who described the cultural literacy as "the oxygen of social discourse...Hirsch, together with two colleagues, identified about 5000 terms and phrases that ...constitute the contents of cultural literacy in the social and natural sciences." Shamos (1995) unpacked this oxygen of social discourse when he defined cultural scientific literacy as a grasp of certain background information communicators must assume their audiences already have, this is the hidden key to effective education. The weakness of cultural scientific literacy according to Shamos (1995) is that if all one needed to be scientifically literate were basic information or vocabulary then we could become scientifically literate by rote. Shamos (1995) added that people who are classified as culturally literate may be able to recognize the science terms used in the media, but for most, their knowledge of science ends there.

Closely tied to the concept of cultural scientific literacy, was an interpretation of scientific literacy developed by Hazen and Trefil (1990, cited in Laugksch 2000). They believed that "a scientifically literate person should be able to place the news of the day about science in a meaningful context" (ibid:80). The similarity of the their interpretation with cultural literacy lies in the fact that rather than select terms and phrases, as Hirsch did, to define the contents of scientific literacy, they "selected 18 general principles of science that cover a range of topics from absolute zero to X-rays" (ibid). At this juncture it is important to emphasize that while cultural literacy, and its ally, proposed by Hazen and Trefil (1990, cited in Laugksch 2000), seem to be a content-oriented and thus unfavourable, the importance of content must not be underestimated. Indeed, as pointed out by Taylor & Vinjevold (1999) one of the greatest weaknesses of many of our teachers is their low levels of conceptual knowledge. Kolstoe (2000) in his attempts to teach science for citizenship focused on two distinct kinds of science knowledge that we need to engage with. First, knowledge about science in the making, or "frontier science," and second, textbook science or "ready made science" (ibid:650). I contend that if we know the latter, it is a start to better teaching. But, if we know them both, it will, for example, help to raise consciousness about disagreements in science. Enough said about the merits of content, let's return to the discussion of cultural literacy.

This cultural literacy definition came under heavy criticism according to Kliebard (1989, cited in Zuzovsky 1997) and another term "functional literacy" emerged. Functional literacy was similar to Shen's (1975, cited in Shamos 1995) civic literacy. It is viewed as the level of understanding science and technology needed to function minimally as citizens and consumers in our society. Shamos (1995) believed that functional scientific literacy requires that individuals transcend the command of a science lexicon, and are able to converse, read and write coherently. The concept of functional scientific literacy is very similar to the Bork's (1999) conception of literacy as a basic competency in a given area; the primary example is reading literacy, the ability to read at a functional level.

Alongside the ongoing discussion about cultural and functional literacy in the 1980s, Laugksch (2000:77) provides yet another contribution to the development of the concept of scientific literacy from Branscomb in 1981, namely, "the ability to read, write, and understand systematized human knowledge." This interpretation of scientific literacy led to eight different categories of scientific literacy, like professional, journalistic or science policy literacy. Clearly, the multidimensional approach to scientific literacy was beginning to be expressed in the multiple foci of both functional literacy, as espoused by Miller (1983, cited in Shamos 1995), and Branscomb's (1981, cited in Laugksch 2000) interpretation of the concept.

For functional literacy, Miller (1983, cited in Shamos 1995) indicated three requirements – not only the mastery of basic vocabulary, and the understanding of science processes, but also the understanding of the impact of science and technology on society and an active, intelligent involvement in public science policy debates. There were two interesting developments that emerged from Miller's three requirements.

First, Arons (1983, cited in Laugksch 2000) included Miller's three requirements in a collection of twelve attributes of a scientifically literate person that he considered important. Arons (ibid:78) focused on the ability to "correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional lives." Yet again, it is clearly noticeable how the definitions were becoming all inclusive, which indicates the evolution of the concept of scientific literacy towards multidimensionality.

Second, Shamos (1995) argues that Miller's interpretation of scientific literacy is an oversimplification of the concept as everyone knows some facts of nature and has some idea of what science is about. Shamos (1995) is more inclined to levels of scientific literacy as defined by the following three interpretations of the concept which build upon one another. The three interpretations are cultural, functional and true scientific literacy.

Shamos (1995) contends that true scientific literacy entails that the individual actually knows something about the overall scientific enterprise. He or she is aware of some of the major conceptual theories that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of the experiment in science. Shamos (1995) accepted that this definition of scientific literacy puts science beyond the reach of many educated individuals.

Perhaps a definition of scientific literacy that is within the reach of all of us is that offered by Baarah & Volk (1994). The latter contend that the scientifically literate person understands how science, technology and society influence one another, and is able to use this knowledge in everyday decision making. Baarah & Volk (1994) adapted this interpretation of scientific literacy from the American Association for the Advancement of Science - AAAS (1989) and Yager & Harms (1981).

Baarah & Volk (1994) also explored the comprehensive definition of scientific literacy that was generated by Project Synthesis in the early 1980s. The purpose of Project Synthesis was to "examine the countenance of science education as it exists at the pre-college level and to make basic recommendations regarding future activities in science education" (Karl and Harms 1981, cited in Baarah & Volk 1994:9). In defining the ideal state of science education, the researchers of Project Synthesis began with the assertion that there are four broad goals that justify the inclusion of science in the school program. The goal clusters describe the scientifically literate person as:

a) One who can utilize science for improving his/her own life and for coping with an increasingly technological world;

b) One who can deal responsibly with science related society issues;

c) One who can acquire the scientific and technological knowledge appropriate for his/her academic needs; and

d) *One who has an awareness of the nature of basic and scope of a wide variety of science and technology related careers open to students of varying aptitudes and interests.*

(Baarah & Volk 1994:10)

The four goal clusters are thus (1) Personal Needs, (2) Societal Issues, (3) Academic Preparation and (4) Career Education/Awareness. Thus science education, as operationalized by Project Synthesis Goal Clusters, incorporates far more than traditional content-laden instruction. Instead, it reflects a strong general education approach. That is, the Project Synthesis Goal Clusters describe an educational thrust that might be deemed appropriate for all citizens. Eisenhart, Finkel and Marion (1996, cited in Zuzovsky 1997) further emphasized the ability to use scientific and technological knowledge. They viewed scientific literacy as a blend of the ability to act (not merely to know) and the promise of widespread use. Literate persons not only possess knowledge, but they use knowledge in varied contexts and for worthwhile purposes and in a socially responsible way. The ability to use knowledge and act involves the:

a) understanding of how science related actions impact the individuals who engage in them,

b) understanding the impact of decision on others, the environment and the future;

c) understanding the relevant science content and methods; and

d) *understanding the advantages and limitations of scientific approach*

(Eisenhart, Finkel and Marion 1996, cited in Zuzovsky 1997:233).

Scientific and technological literacy thus became a multi-dimensional construct (Miller 1983, cited in Shamos 1995). In trying to describe the complexity of this construct, Scribner (1986, cited in Zuzovsky 1997) offered three different metaphors to capture the different meanings of scientific and technological literacy: 1) Literacy as adaptation – refers to what others called functional literacy; 2) Literacy as power- refers to literacies that enable individuals or groups to claim a voice and place in society; and 3) Literacy as state of grace represents the self-enhancing potential of literacy, the special virtues attributed to literate persons. She suggested "ideal literacy" to be the "simultaneously adaptive, socially empowering and self enhancing" kind.

There were three other interesting interpretations of scientific literacy that emerged in the mid-1990s. The first interpretation was developed by an advisory committee set up by the minister of education in the Netherlands to introduce public understanding of science as a subject in its own right. As mentioned above, scientific literacy is sometimes equated to the public understanding of science. The advisory committee affirmed the multidimensional nature of the concept of public understanding of science. They described the concept of public understanding of science as a vision of "all citizens…(having) some idea of the origin, nature and impact of scientific knowledge…these citizens should also have insight into a scientists activities, e.g. designing and using models, developing theories, and carrying out experiments. Moreover, they should be aware of the important scientific and technological aspects of many political and social decisions in our society" (De Vos and Reiding 1999:713).

This interpretation of scientific literacy, or public understanding of science, is very similar to Shamos's (1995) concept of true scientific literacy. Shamos (1995) spoke about the foundations of science, how they were arrived at, and why they are widely accepted, etc. Therefore, this interpretation of science, might, as Shamos (1995) accepted for true scientific literacy, be beyond the reach of many educated individuals.

The second interpretation of scientific literacy in the mid-1990s came from Fensham (1995:36) who contends that scientific literacy, according to TIMSS, includes "the residue of conceptual learning, contextualized in real world situations, and reasoning and social impacts of mathematics, science and technology." This version of scientific literacy suggests that a conceptual learning approach is a pre-requisite for scientific literacy. The other multidimensional interpretations of scientific literacy focused on the skills and abilities required of someone who is technologically literate. For example, dealing with science related issues in society, and Fensham (1995) mentions this too. But, he adds a process of conceptual learning as a prerequisite for scientific literacy. This conceptual learning requirement also intimates that to be scientifically literate, one needs to have more than a simple vocabulary of scientific terms. Despite the process orientation of the definition provided by Fensham (1995), in a later publication (Fensham 1999) he concedes that the actual scientific literacy test administered by TIMMS in 1996 was largely (45 minutes) on the recall of science content. The rest of the time (15 minutes) was combined for questions on "reasoning and social utility in science and technology" (ibid:759).

The third interpretation of scientific literacy in the mid-1990s came from Bybee (1995). He described four dimensions of the concept scientific literacy in the true spirit of multidimensional scientific literacy. The four dimensions are functional literacy, conceptual and procedural literacy, and perspectives of science and technology. Bybee's (1995) interpretation of functional literacy differed from that described above as he confined the concept to scientific vocabulary while Miller (1983, cited in Shamos 1995) added the understanding of science processes, understanding of the impact of science and technology on society, and an active, intelligent involvement in public science policy debates. Conceptual and procedural literacy imply that "learners should relate information and experiences to conceptual ideas that unify the disciplines of science. In addition, literacy in science must also include abilities and understandings relative to the procedures and processes that make science a unique way of knowing" (Bybee 1995:29). The fourth dimension, perspectives of science, includes "the history of scientific ideas, the nature of science and technology, and the role of science and technology in personal life and society" (ibid). The four dimensions of Bybee's (1995) interpretation of scientific literacy manifest themselves in the National Science Education Standards (NSES) of America, described below.

In 1996, the National Academy of Sciences produced the NSES, which is part of the U.S. government's approach to reform education, an approach that involves setting national goals and the standards for meeting them" (DeBoer 1999:590).

According to the NSES,

> "*Scientific literacy means that a person can ask, find or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social*

conversation about the validity of the conclusions. Scientific literacy implies that a person can identify issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately"

(ibid:590-91).

The NSES definition of scientific literacy is very broad and includes all the goals of science education. As such it is could perhaps be described as too ambitious, but it does encompass all the elements of the concept scientific literacy. Once again, the multidimensional nature of scientific literacy is expressed in this highly evolved state of the concept. According to Laugksch (2000:79) "there is a high degree of congruence in the conceptualizations of scientific literacy between the National Research Council (National Academy of Sciences) responsible for the NSES and Project 2061" undertaken by the American Association for the Advancement of Science (AAAS). To avoid repetition, and because the NSES is more extensive (goes beyond standards for learners to standards for teaching, professional development, and assessment – see Laugksch 2000) than Project 2061, only the NSES interpretation of scientific literacy was discussed above.

Fensham (1999) offers another interpretation of scientific literacy developed by the Science Functional Expert Group (SFEG) of the PISA Project. According to the SFEG, scientific literacy entails "being able to combine science knowledge with the ability to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it by human activity" (ibid:761). This definition is a restatement of the application of scientific knowledge (like practical scientific literacy), and the impact of humans on the natural world. The definition is silent on the corollary of human impact on the natural world, i.e. the impact of the unnatural world, as in the case of depleted levels of ozone, on humans. Interestingly this is yet another instance where ecological impacts are brought to the fore in a definition of scientific literacy. Eisenhart, Finkel and Marion (1996, cited in Zuzovsky 1997:233) also mentioned quite explicitly that scientific literacy entails developing an "understanding the impact of decision on others, the environment and the future." More recently, Eilks (2000:16) insisted on the inclusion of "societal and ecological dimensions" in the teaching of chemistry. Fensham (1999) goes onto emphasize that the SFEG (1998) definition of scientific literacy is also a multidimensional construct similar to those discussed above. For example, the SFEG is bent on, amongst others, process skills, relevance of content to everyday situations, scientific investigation, and enduring relevance of concepts or content.

One of the latest additions to the advancement of scientific literacy is "the centrality of communications skills" (Hand et al 1999:1022). To this end, the importance of writing in science is a major focus in the works of Hand et al (2000) and Hanharan (1999). They argue that enhanced writing skills in science can lead to a variety of benefits like: representing scientific ideas better, keeping better records, solving problems, clarifying ideas, improved debate on science issues; and informed speculation about alternative scientific approaches. These researchers' works focus on the use of, for example, journal writing or group writing, and have yielded positive impacts on teaching and learning practices. The results though, cannot be generalized, because if "used by a teacher with a different philosophy and without genuine affirmation of the students' worth, it might not have the effect in that it had in this class, it might even cause harm" (Hanharan 1999:714). The relationship between writing skills and scientific literacy is important as described above, but the definition of the concept of scientific literacy has not yet been altered by research into writing skills. Nonetheless, as the relationship is receiving attention in the international research community, it was included in the discussion of the evolution of the concept of scientific literacy.

In conclusion to the exploration of the trajectory of the concept of scientific literacy, it is clear that the concept has evolved from a being a simple contribution to enhance the quality of general education in the 1930's to a sophisticated multidimensional concept in the 1990's. The multidimensional approach to scientific literacy embraces understanding of how science related actions impact the individuals who engage in them, understanding the impact of decisions on others, the environment and the future; understanding the relevant science content and methods; and understanding the advantages and limitations of scientific approach. Table 2.1. below attempts to summarize the chronological evolution of the term scientific literacy from the 1930s to date as described above.

Period or date	**Person(s) responsible**	**Scientific Literacy …**
1930s	Dewey	was conceived as the unique contribution of science to general education.
1952	Conant	denoted a broad understanding of science.
1958	Hurd	was an understanding of science and its applications to social experience and science was integral to economic, political and personal issues.
1960s	Various	used as a major educational aim in the era of sloganeering.
1960s	Shamos	as knowing science in a humanistic way or feeling comfortable in reading or talking with others about science in a non-technical way.
1963	Hurd	is knowledge of key science concepts, relating these concepts in a coherent way, the social relevance of science, and the limitations of science.
1963	Koelsche	as the knowledge and skills required to read and understand science as presented in the media.
1966	Pella, O'Hearn and Gale	entailed interrelations between science and society; ethics of science; nature of science; conceptual knowledge; science and technology; and science in the humanities.
1971	NSTA	one who uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and his environment, and understands the interrelationships between science, technology and other facets of society, including social and economic development.

1970s	Shen - Practical scientific literacy	included the kind of scientific and technical knowledge that can immediately be put to use to help to solve practical problems.
1970s	Shen – Civic Literacy	was a demand for knowledge that would enable citizens to become more aware of science-related issues, so that in a democratic society, they would have the power to affect public and technological policy.
1981	Branscomb	the ability to read, write, and understand systematized human knowledge.
1983	Arons	correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional lives.
1987	Hirsch - cultural literacy	is a grasp of basic information needed to thrive in the modern world, something that was then translated into possession of a lexicon of scientific terms.
1989	Unknown - functional literacy	the level of understanding science and technology needed to function minimally as citizens and consumers in our society.
1980s	Project Synthesis	One who can utilize science for improving his/her own life and for coping with an increasingly technological world; One who can deal responsibly with science related society issues; One who can acquire the scientific and technological knowledge appropriate for his/her academic needs; and One who has an awareness of the nature of basic and scope of a wide variety of science and technology related careers open to students of varying aptitudes and interests.

1986	Scribner - ideal literacy	should be simultaneously adaptive, socially empowering and self enhancing.
1990	Hazen and Trefil	a scientifically literate person should be able to place the news of the day about science in a meaningful context...selected 18 general principles of science that cover a range of topics from absolute zero to X-rays.
1994	Baarah & Volk	requires a person to understand how science, technology and society influence one another, and is able to use this knowledge in everyday decision making.
1995	Shamos – true scientific literacy	entails that the individual actually knows something about the overall scientific enterprise. He or she is aware of some of the major conceptual theories that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of the experiment in science.
mid-1990s	Netherlands Ministerial Advisory Committee	all citizens...(having) some idea of the origin, nature and impact of scientific knowledge...these citizens should also have insight into a scientists activities, e.g. designing and using models, developing theories, and carrying out experiments. Moreover, they should be aware of the important scientific and technological aspects of many political and social decisions in our society.
1995	Fensham	includes the residue of conceptual learning, contextualised in real world situations, and reasoning and social impacts of mathematics, science and technology.

1995	Bybee	the four dimensions are functional literacy, conceptual and procedural literacy, and perspectives of science and technology.
1996	Eisenhart, Finkel and Marion – Scientific Literacy is a Multidimensional construct	understanding of how science related actions impact the individuals who engage in them, understanding the impact of decision on others, the environment and the future; understanding the relevant science content and methods; and understanding the advantages and limitations of scientific approach.
1996	NSES	means that a person: can ask, find or determine answers to questions… has the ability to describe, explain, and predict natural phenomena..(can) read with understanding articles about science… can identify issues underlying national and local decisions…can evaluate the quality of scientific information…can pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
1998	SFEG	being able to combine science knowledge with the ability to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it by human activity.
1999	Jenkins	Citizen Science: science, which relates in reflexive ways to the concerns, interests, and activities of citizens as they go about their everyday business.

Table 2.1. The Evolution of Scientific Literacy from the 1930s to the 1990s

While there are many options to choose from Table 2.1, the interpretation that I am most comfortable with, relative to this study, is a combination of Shen's (1975, cited in Shamos 1995) practical literacy and civic literacy concepts. Therefore, the working definition of scientific literacy in this study 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 (practical literacy), and they would have the power to affect public and technological policy (civic literacy).

This working definition of scientific literacy is aligned to the scientific literacy test in this study for two principal reasons. First, by and large, the questions in the scientific literacy test attempt to transcend the assessment of scientific vocabulary (the so-called lexical knowledge of science). Some of the scientific literacy questions are aimed at increasing awareness of science-related issues, and the application of that knowledge in real life situations (practical literacy). For example, one question explores the influence of the force of inertia on a passenger travelling in a car when the car changes direction, and another question or focuses on the effect on the boiling point of the contents of a cooking vessel when salt is added. Yet another question deals with how pain experienced by the hand can be reduced when catching an object.

The second reason why this working definition is chosen for scientific literacy is that some of the scientific literacy questions in this study are designed to test whether students have the ability to affect public and technological policy (civic literacy). For example, the question on global warming tests if students know whether carbon dioxide gas is responsible for this phenomenon. Another question looks at the role of the layer of ozone in protecting the earth against the harmful ultraviolet rays of the sun, and the question on HIV/AIDS, tests if students understand all known methods of transmission of the virus. Thus, if students are in the know, they can respectively affect public and technological policy on reducing the emission of carbon dioxide gas, protecting of the ozone layer, and preventing the spread of HIV/AIDS.

The choice of a working definition of scientific literacy does not suggest that this definition is a universally acceptable definition. The concept of scientific literacy "has defied precise definition since it was introduced...many attempts have been made to define it, but none has yielded anything that approaches universal acceptance" (DeBoer 1999:582). In fact, scientific literacy is so broadly defined in the literature that it has "come to be an umbrella concept to signify comprehensiveness in the purposes of science teaching" (Roberts 1983, cited in Laugksch 2000:73). Therefore, the selection of a working definition then, is purely for the purposes of creating a theoretical basis to inform the scientific literacy questions in this study, as described above.

The foregoing analysis of scientific literacy provided a narrative and a tabular description of the evolution of the concept of scientific literacy and then distilled and justified a working definition of the concept of scientific literacy in the context of this study. The literature review now proceeds to explore the concept of technological literacy, to describe its evolution and then to distill a working definition in the context of this study.

2.3.4. <u>Technological Literacy</u>

Just as there is an assortment of conceptions of scientific literacy, so too are there a variety of understandings related to technological literacy. The different conceptions of technological literacy will be described below; however, it must be emphasized in advance that there is a dearth of literature available on the technological literacy. There are two main reasons for this limitation. First, more attention has been focused on the concept scientific literacy that spawned the concept of technological literacy. Technological literacy is a relatively new concept compared to scientific literacy. The origins of the concept scientific literacy were traced back to the 1930s and the concept of technological literacy was only alluded to in the 1970s when the concept of practical scientific literacy was presented by Shen (1975, cited in Shamos 1995) [see Table 2.1. pp.29-32]. Second, technological literacy is commonly subsumed within the scientific and technological literacy discourse. Regardless, of the limitations in the literature, every effort will be made to provide an insightful exposition of the different conceptions of technological literacy.

At the outset of this review on technological literacy, I want to problematize the notion of technological literacy and offer a personal perspective on the nature of the technological literacy that will be measured in this study. Waetjen (1993) contends that technology education does not have a structured body of knowledge, of organizing concepts, of underlying and fundamental principles, ideas that define an academic discipline. Therefore, it follows that there is no valid way of determining curriculum content. Hence, students cannot attain technological literacy if technology education has no structured domain of knowledge. Hook (2001:32) confirms the uncertainty associated with the nature of technology education when he states: "For years, most technology programs have wandered aimlessly, though with good intentions, through a maze of changes and choices with no road map to show the way."

I concur with the Waetjen (1993) interpretation that technology education lacks a structured domain of knowledge and therefore it is difficult to measure technological literacy as you would scientific literacy that has a defined curriculum content. Barnett (1995) contends that the lack of an agreed meaning for technological literacy reflects a widespread confusion about how the study of technology should be pursued. Todd (1991, cited in Waetjen 1993) says that we are unsure as to whether we are using technological literacy to represent a slogan, a concept, a goal or a program. What is surprising is that despite the confusion that reigns about technological literacy, there are publications in which sweeping statements are made about technological literacy levels without substantiation. For example, according to the Canadian Academy of Engineering (2000), there is a lack of technological literacy among the public and the technological literacy of many university graduates is open to question.

Based on the foregoing discussion on the lack of a structured domain of knowledge for technology and the confusion surrounding the concept, my theory is that this study does not measure technological literacy in the true sense. What is measured in this study is 'intuitive technological literacy' as the students did not take the subject at school level, and if they had exposure to technology education, it had no structured domain of knowledge. The concept of intuitive technological literacy is the author's contribution to the slew of terms that have been generated in developing an understanding of technological literacy.

According to the literature, it is the author's understanding that there are three distinct conceptions of technological literacy. The earliest conceptions of technology placed emphasis on conceptual material, e.g. understandings, knowledge, decision making, etc. Thereafter, there was an interim phase in the evolution of the concept of technological literacy that placed emphasis on tool skills, shaping materials and modeling. Subsequently, technological literacy evolved into a multidimensional concept, like scientific literacy did, to include, amongst others, applications of technology in new situations, the appreciation of values and societal issues, and the use of research skills to arrive at technological solutions.

With regard to the first conception of technological literacy that emphasized conceptual material, Waetjen (1993) concluded that technological literacy requires the ability of an individual to decode and encode technological messages. Encoding and decoding entail being able to understand and use words and their meanings. This emphasis on theoretical understanding was further demonstrated in Charp's (1996) incorporation of the concept technological literacy into the general concept of literacy. Charp (1996) believes that literacy includes the basic skills of reading, writing and arithmetic as well as computer and other technology related skills in the context of the workplace. Hayden (1989, cited in Waetjen 1993) furthers Charp's (1996) interpretation of the concept of technological literacy. He describes technological literacy as having knowledge and abilities to select and apply appropriate technologies in a given context. Perhaps this interpretation forms a bridge between the first conception of technology (emphasis on conceptual material) and the interim phase in the evolution of the concept of technological literacy (emphasis on skills).

The interim phase in the evolution of the concept of technological literacy placed emphasis on tool skills, shaping materials and modeling. This is a narrow conception of technological literacy because it includes computer skills and the ability to use computers and other technology. The interim conception of technological literacy still prevails in some contexts. For example, the former president of the United States described technological literacy as "computer skills and the ability to use computers and other technology to improve learning, productivity and performance..." (Clinton 1997:1).

President Clinton and Vice-President Gore of the United States introduced the Technological Literacy Challenge in 1996, which made the integration of technology into the classroom a national priority. To facilitate this priority, they set goals pertaining to the supply of training and support to all teachers, multimedia computers in all classrooms, connection to the Information Superhighway, and increased availability of effective software and on-line resources (Snyder 1997). The way in which technological literacy is perceived within the Technological Literacy Challenge of 1996 in the United States reinforces the interim definition of technological literacy which emphasized tools skills like computer skills and the ability to use computers and other technology. Bybee (2000) adds that the general lack of understanding of technology in society is confounded when we equate the theme of technology education with the use of computers.

In many instances, this interim phase in the evolution of the concept of technological literacy also listed conceptual knowledge together with tool skills as the requirement for technological literacy. For example, Croft (1991, cited in Waetjen 1993) proposed that a technologically literate person should possess basic literacy skills required to solve technology problems but also apply knowledge, tools and skills for the benefit of society; and ability to describe the basic technology systems of society. Also, Steffens (1986, cited in Waetjen 1993) claims that technological literacy involves knowledge and comprehension of technology and its uses, skills (tool and evaluation skills), and attitudes about new technologies and their application.

The interim conception of technological literacy as a combination of knowledge and skills did not remain static. Some authors like Fleming (1987, cited in Saskatchewan Education 2000) who subscribed to the multidimensional approach (particularly emphasizing societal influences) of technological literacy actually refined understandings of what constitutes knowledge and skills in technological literacy. Fleming (1987, cited in Saskatchewan Education 2000:1) claimed that:

> *in order to achieve an informed, balanced and comprehensive analysis of the technological influences on their lives and then be able to act on the basis of their analysis, students require certain levels of knowledge, skills and abilities. These included understanding that technology includes hardware, know-how, cultural needs and desires, and economic and political decision making; understanding how technology shapes and is shaped by society; understanding that technological issues involve conflicting assumptions, interpretations and options; having the necessary data collection and decision making skills to make intelligent choices; having the ability and desire to take responsible action on societal issues."*

Therefore, the knowledge and skills required of a technologically literate person had evolved from being confined to conceptual knowledge together with tool skills as conceived by Croft (1991, cited in Waetjen 1993) and Steffens (1986, cited in Waetjen 1993) above, to embrace knowledge pertaining to societal, economic and political decision-making as well as research skills.

The interim conception of technology inspired a multidimensional approach to conceiving technological literacy. Thomas and Knezek (1994, cited in Charp 1999) were emphatic that technological literacy transcended the ability to evaluate and use a variety of common technology applications as suggested in the interim phase in the evolution of the concept technological literacy. They emphasized that technological literacy also embraced the ability to innovate and invent ways of applying technology in challenging new situations; awareness of technology-related careers and of factors critical to success in those careers; and understanding and sensitivity to societal issues related to technology.

Some of the ideas from Thomas and Knezek (ibid) like applying technology in new situations and sensitivity to societal issues, resonate strongly with some of the critical outcomes for technology as envisaged in the Discussion Document of C2005 (DOE 1997a). For example, specific outcome one in the technology learning area of C2005 entails understanding and applying the technological process to solve problems and satisfy needs and wants; and specific outcome two embraces sensitivity to problems, dilemmas, issues and choices in society.

Fleming (1987, cited in Saskatchewan Education 2000) refined the societal approach to technological literacy. He described technological literacy "as the intellectual processes, abilities and dispositions needed by individuals to understand the link between technology, themselves and society in general" (Saskatchewan Education 2000:1). This societal focus provided by Fleming (1987, cited in Saskatchewan Education 2000) resonates with the White Paper on Science and Technology (DACST 1997:4) which insists that a society "must ensure that its members develop and continually update the knowledge, competencies, abilities and skills that are required to produce innovative products and services." Both Fleming (1987, cited in Saskatchewan Education 2000) and the White Paper on Science and Technology (DACST 1997) endorse the idea that technological literacy is about developing awareness of how technology is related to the broader social system, and the political, cultural and economic frameworks which shape it. The capacity to make critical judgments involving technology increases the ability of citizens to use such knowledge to shape and influence their environment.

Another important contribution provided by Fleming (1987, cited in Saskatchewan Education 2000) to the development of an understanding of the concept technological literacy pertained to values. He stated that values also influence intellectual processes, since anything that involves choice also involves consideration of whose values are shaping a particular technological development. There is a similarity here between the development of the concepts of technology and technological literacy. Naughton (1990) believed that technology can be informed by other kinds of knowledge like experience, craft knowledge and feelings about a particular product, so too does Fleming (1987, cited in Saskatchewan Education 2000) believe that technological literacy involve values.

This concept of values and its influence on technological decision is interesting. On the one hand, Fleming believes that there is a subjective bias in the technological choices that we make. On the other hand, a later interpretation of technological literacy (Dugger 2000) encourages objectivity if one is technologically literate. Specifically, Dugger (2000:10) states that a technologically literate "is comfortable with and objective about technology..." Quite frankly, I concur with Fleming, as it is impossible to ignore values when technological choices are being made.

The foregoing discussion on technological literacy has shown the developments of the concept of technological literacy. First, there was an emphasis on conceptual material, then an emphasis on technological skills; and finally a multidimensional concept emerged. The latter included applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions.

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).

The above interpretation of technological literacy is the second working definition derived in this chapter, the first working definition pertained to scientific literacy. The technological literacy working definition strikes a chord with this study because it is aligned to the test for technological literacy in three specific ways.

First, the working definition speaks of the analysis of pros and cons of a technological development to examine its potential benefits and demerits, and its potential costs. This is the very nature of two of the questions in the technological literacy test which relate to the factors that are taken into consideration when purchasing a cell phone, and the impact of the Internet on society. The question on the cell phone, in accordance with specific outcome four in the technology learning area as outlined in the Discussion Document of C2005 (DOE 1997a), explores whether students are able to select and evaluate systems. This question allows students to analyze the pros and cons of different types of cell phones that are available on the market by reviewing their characteristics, functions and costs. Similarly, the question on the Internet tests whether students understand the impact of technology. In this question, students can examine electronic communication and quick access to information, and their impact on society, the economy and the natural environment.

Second, the underlying political ramifications of technological literacy alluded to in the working definition above are tested when the students are requested to comment on whether the drug AZT should be made available in South Africa. The South African government is clearly opposed to making the drug AZT, and its successor Nevirapine, available in public hospitals. Specific outcome seven in the Discussion Document of C2005 (DOE 1997a) encourages students to understand how technology might reflect different biases. Moreover, students need to understand how access to technology has been denied in some cases.

Third, the impact of social forces, mentioned in the working definition of technological literacy, cannot be underestimated. The technological literacy question pertaining to the resolution of sanitation problems at an informal settlement brings this point to the fore. This particular question also has a research method built into its different components, which is yet another feature of the working definition of technological literacy. In solving the sanitation problem, the students need to understand what the community envisages as a solution to the problem. The students cannot simply proceed with a solution blind of the solutions offered by the residents of the informal settlement as the intervention will never be sustained if the locals do not own it.

The two concepts of scientific and technological literacy will now be problematized further in attempting to answer the more controversial question of whether scientific and technological literacy are necessary.

2.4. Is Scientific and Technological Literacy Necessary?

There are both optimistic and pessimistic responses to this question of whether scientific and technological literacy is necessary. The optimistic responses offer empowerment of the people and economic prosperity for South Africa. The pessimistic responses tend to be peppered with cynicism but they are also convincing. I will first elaborate the optimistic and then the pessimistic responses from the literature.

Some of the optimists include Stahl (1994), Doke (1998) and Dugger (2000). Stahl (1994:44) maintains that "scientific and technological literacy enables the general public to understand events and ideas related to scientific discovery and technological development, and thereby to exercise the rights and responsibilities of citizenship in a democratic society." These views are similar to those of Fleming (1987, cited in Saskatchewan Education 2000) discussed above. Stahl (1994) goes on to impress upon us that scientific literacy will help to distinguish fact from misinformation, and to be aware of political and cultural biases when policy decisions are taken.

Doke (1998) impresses upon us that science and technology are the keys that will unlock a prosperous future for South Africa. "South Africa needs to nurture science and technology for its children to leap forward armed with knowledge into the next millennium...People with scientific insight gain power over their environment. Scientific enquiry forms a core competency that supports technological enterprise. If that core competency is lost within a nation, that nation becomes powerless against its competitors" Doke (1998:1). South Africa needs to capitalize on its scientific and technological wealth to advance technologically and economically as a nation.

Dugger (2000) contends that technological literacy enables people to develop knowledge and abilities about human innovation and action. There are elements of the thinking of Stahl (1994), Doke (1998), and Fleming (1987, cited in Saskatchewan Education 2000) in Dugger's (2000) views. Dugger (2000) reiterates the importance of a technologically informed citizenry to be involved in decision-making processes, as endorsed by Stahl (1994) and Fleming (1987, cited in Saskatchewan Education 2000). He then echoes the economic outcomes of a technologically literate society as Doke (1998) did, "in (helping the) nation maintain and sustain economic progress" (Dugger 2000:10).

Bauer (1992) was one of the principal pessimists on the necessity for scientific and technological literacy. Bauer (1992) provides a list of reasons as to why scientific literacy is necessary but then goes on to contest each of these reasons:

First, it is apparent that knowing science enables people as voters and as consumers to make better decisions. Bauer (1992) believes that this is not necessarily true, as even brilliant scientists have, on occasion, not been able to arrive at correct decisions. Stahl (1994) offers an interesting rebuttal to this undesirable reality. He asserts that people who are scientifically literate have a general comprehension of principles rather than an encyclopedic knowledge of facts. Therefore, even scientists can arrive at wrong decisions when they are out of their depth. However, that is not a good reason not to pursue specialist interest in a particular field.

Second, supposedly understanding modern technology brings economic good and thereby aids national security. This claim is supported by the assertion that science spawns technology. However, even though the quality of science has been unexcelled in the United States in the past half-century, it is Japan that has excelled technologically. The relationship between science and technology is anything but straightforward. That Japan has excelled technologically cannot be disputed but surely there are other factors beyond just technological acumen that result in economic prosperity. Amongst other attributes, the Japanese are diligent and industrious people and economic success also hinges on these factors.

Third, allegedly scientific knowledge supplants superstition. This is not necessarily true in that many scientists still cling to superstitious views despite their scientific knowledge. Indeed, people, be they scientists or not, are influenced by a variety of factors like personal belief systems and misconceptions. Thus, this eventuality of clinging to personal beliefs can prevail.

Fourth, maybe if we learn to think scientifically, that is, in terms of predictable consequences of actions, then our actions will become more rational. But scientists do not exhibit a higher level decision-making or behaviour than others. As mentioned above, beyond their fields of expertise, scientists flounder as any normal person would when making decisions. Yes, scientists and normal citizens do cling to certain principles of science but these do not reign exclusively when decisions are made.

Fifth, perhaps familiarity with the scientific method will lead to a more ethical attitude. But, behaviour is not directly governed by intellect. This can also hold true particularly because we all have values and biases that influence the decisions that we take. The issue of values was discussed above relative to technological literacy and it was concluded that values also influence intellectual processes since anything that involves choice also involves consideration of whose values are shaping a particular technological development.

Indeed, it is difficult to dismiss the cynical, yet convincing, arguments presented by Bauer (1992) as to why scientific literacy is not necessary. In contrast, Stahl (1994) is convinced that critical citizenry will be a natural outcome of scientific literacy, and Doke (1998) impresses the economic empowerment associated with scientific and technological literacy. However, the realities presented by Bauer of scientists not being able to arrive at correct decisions or other factors beyond just technological acumen that result in economic prosperity, do generate a sense of doubt as to whether scientific and technological literacy is necessary. Moreover, the influence of personal belief systems values, biases, and misconceptions on decision-making processes cannot be ignored (Bauer 1992).

But to acquiesce to Bauer (1992) would be tantamount to surrendering all hope of scientific, technological and economic advancement. Rather, one should acknowledge the challenges outlined by Bauer (1992) and take them into consideration when aspiring towards scientific and technological literacy for all, not scientists exclusively. In any event, most of the criticisms offered by Bauer (1992) pertain to the limitations of scientists, and according to Cross and Price (1999) the apparent dependence on scientists to arrive at correct decisions provides all the more reason to pursue scientific literacy for all, not scientists exclusively. They go on to impress that the reliance on experts has led to the rise of "expertocracy with its accompanying interests, both political and economic, (and that)... is a threat to democracy" (ibid:783).

2.5. Conclusion

This chapter analyzed and traced the evolution of the assortment of conceptions of scientific and technological literacy. The root concepts of science and technology were examined to explain the combined use of the terms as if they were one entity, and to develop clear definitions of the terms. Science and technology were eventually distinguished on the basis of their purposes, scientific activity is to build up knowledge and technological activity is to put knowledge to good use by solving some practical problem. Thereafter, a wide range of perspectives on the two concepts of scientific and technological literacy was presented. The concept of scientific literacy evolved from a being a simple contribution to enhance the quality of general education in the 1930s to a sophisticated multidimensional concept in the 1990s which embraced, amongst others, an understanding of how science related actions impact the individuals who engage in them. The concept of technological literacy evolved from a concept that emphasized conceptual material; to an emphasis on technological skills; and finally into a multidimensional concept, to include applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions. Operational definitions for scientific and technological literacy were also provided to inform this study. Finally the discussion moved on to the necessity for scientific and technological literacy. In this concluding component, the optimistic and pessimistic viewpoints were presented, and it was resolved that to acquiesce to the pessimist Bauer (1992) would be tantamount to surrendering all hope of scientific, technological and economic advancement. Rather, one should acknowledge the challenges outlined by Bauer (1992) and take them into consideration when aspiring towards scientific and technological literacy for all, not scientists exclusively.

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. <u>The Mixed Methodology Research Approach</u>

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. <u>The Process of Developing the Questionnaire</u>

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. <u>The Validation of the Focus Group Interview Schedule</u>

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.

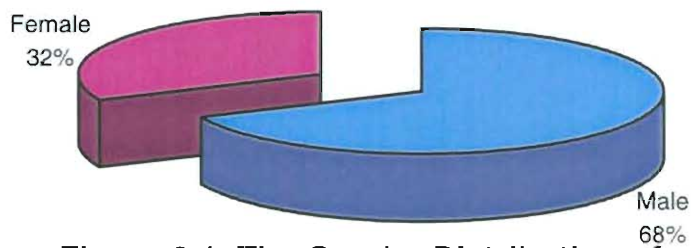

Figure 3.1. The Gender Distribution of the Sample

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.

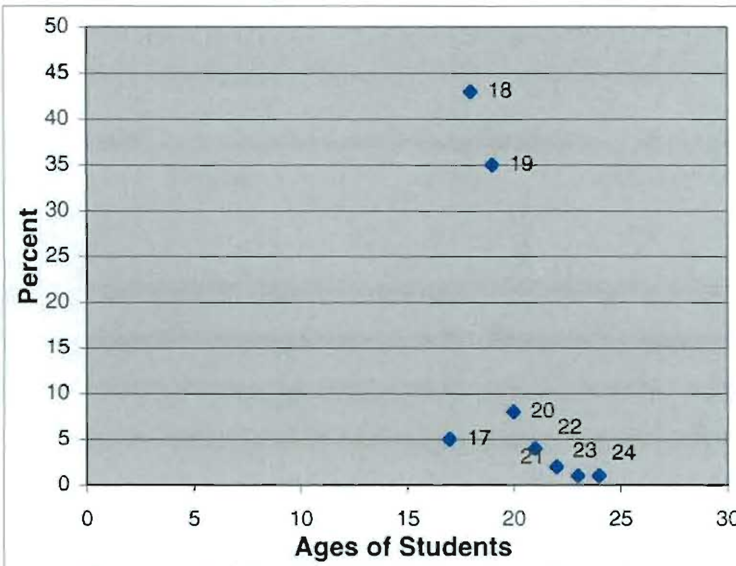

Figure 3.2. The Age Distribution of the Sample

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.

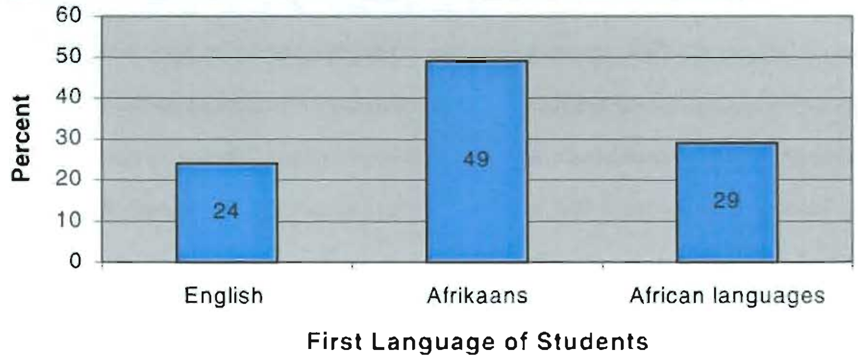

Figure 3.3. The First Language Distribution of the Sample

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.

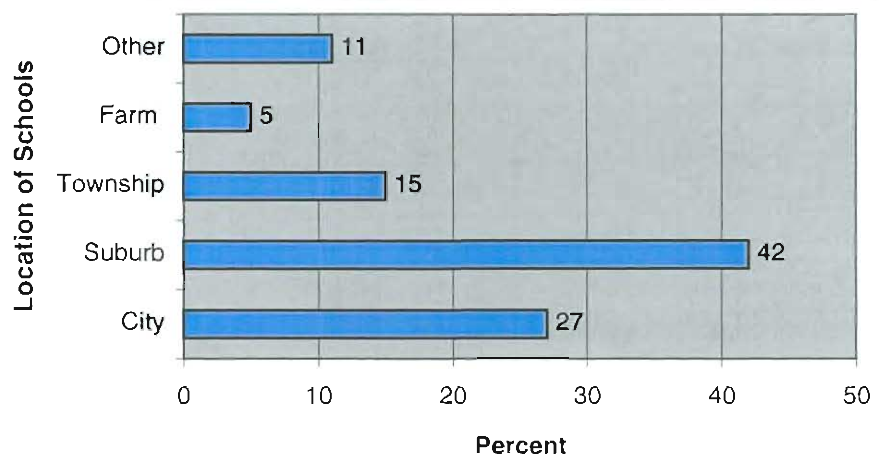

Figure 3.4. The Locations of Schools in the Sample

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.

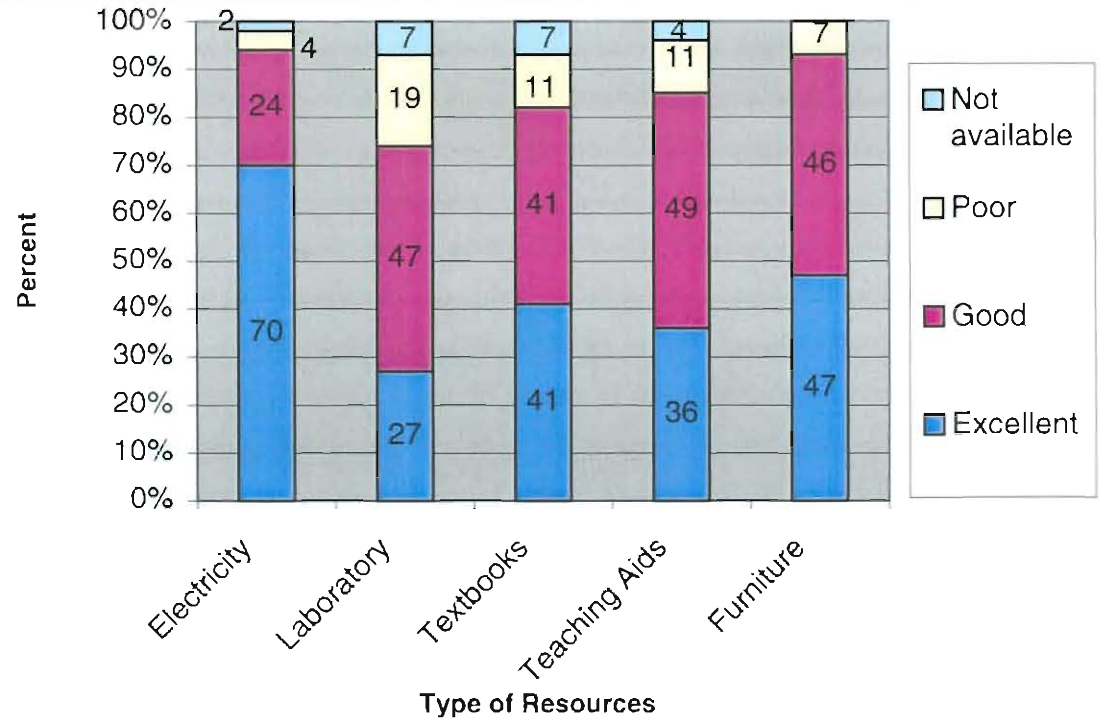

Figure 3.5. The Availability and Condition of Resources in Schools

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.

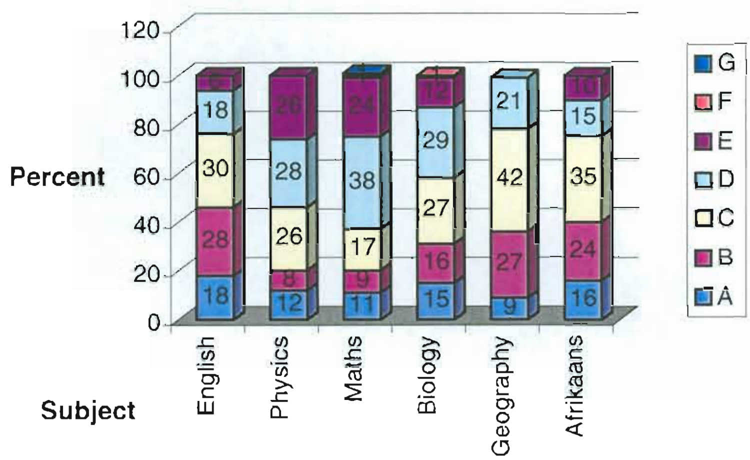

Figure 3.6. The Matric Symbol Distribution in the Sample

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.

Chapter Four

Science and Technology:

Traditional versus Transformational Outcomes-Based Approaches

4.1. Orientation to the Chapter

This chapter is related directly to the first critical question of this thesis, i.e. 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 part of this study because it will examine the effects of the traditional curriculum on the science syllabi and on the teaching and learning practices of the selected students. Further, this question embraces a comparison of the traditional and transformational outcomes-based paradigms to highlight the different emphases in policy and practice vis-à-vis learning and teaching in science. Therefore, the results of critical question one will provide a background against which the scientific and technological literacy levels of students can be understood.

There are three segments to this chapter. The first segment is a comparison of syllabus and policy documents related to each of the two paradigms of teaching and learning. The first segment serves as a preamble to the remaining segments. The second segment is a descriptive statistical discussion of the kinds of teaching and learning experiences of the students. And the third segment is an exploration of relationships that exist between the different teaching and learning experiences of the students. For example, does a chalk and talk approach to teaching correspond with a memorizing of notes learning experience?

4.2. Science and Technology: Traditional versus Transformational Outcomes-Based Approaches to Teaching and Learning

An understanding of the traditional approach to teaching and learning, and the associated syllabus and policy documents, are critical to answering the first critical question in this study as they provide a way to understand the theoretical underpinnings of the actual teaching and learning experiences of the students. Additionally, it would be inappropriate to make assumptions about the theoretical framework of the traditional curriculum when explaining the teaching and learning experiences of the students. Similarly, an exposition of the new transformational outcomes-based approach in South Africa is critical to understand the underlying principles, philosophies, and theories that informed the development of associated questions in scientific and technological literacy tests that were developed for this study.

This first component of the chapter will compare the syllabus and policy differences between the traditional science curriculum and the new transformational science curriculum. The reason for this comparison is to show the different emphases in syllabus and policy vis-à-vis learning and teaching in science.

The following features of the traditional and the transformational science curricula will be examined:

a) Underpinning Learning Theory;
b) Goals;
c) Objectives/Outcomes;
d) Content;
e) Teaching Strategies/Methodologies; and
f) Assessment Strategies.

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

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 were used to provide insight into the nature of the syllabus and teaching practices consistent with outcomes-based education included:

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.

The examination of the key features of the old and the new science policies follows.

4.2.1. <u>Underpinning Learning Theory</u>

According to the CUMSA Discussion Document (DOE 1992a:30), Natural Sciences "concerns itself with imparting knowledge about creation and about the world as it has been changed by mankind, as well as with development of skills and expertise associated with scientific methods of investigation. There were thus two distinct components of the Natural Sciences. First, the imparting of knowledge and second the emphasis on scientific method. The imparting of knowledge was actually the manifestation of the learning theory of Behaviourism. According to Ornstein & Hunkins (1998:133) some of the features Behaviourism entail: "(learning) in small, step by step, simple units…learning is observable and/or measurable…and learning through rewards is preferable than under the conditions of punishment." Sometimes, the traditional science curriculum is labelled as a model of Transmission Learning, which is similar to Behaviorism but does not proceed sequentially.

Van Loggerenberg (2001) contends that traditional curricula were underpinned by the traditional philosophies of Perennialism and Essentialism. Perennialism is rooted in the acceptance of generally agreed-upon knowledge of the past. Such an approach leaves little opportunity for students to create their own meanings of content, and to use students' ideas as a point of departure when designing a learning session. As mentioned above, the CUMSA Discussion Document (DOE 1992a) emphasized the imparting of knowledge and the use of the scientific method as the principal features of the Natural Sciences. Van Loggerenberg (2001) argues that although Perennialism was premised on reason, there was an overwhelming emphasis on a highly academic curriculum, which was content-laden. Hence, Perennialism and the CUMSA Discussion Document (DOE 1992a) vision of the Natural Sciences share a common emphasis on knowledge or content. To fulfil the requirements of a knowledge-based curriculum necessitated a "curriculum (that) is subject-centred where the teacher is viewed as the authority and the expert in the subject field. The dominating teaching methods entail lecturing, oral exposition and rhetoric" (Ornstein & Hunkins 1993:42). Hence, the science curriculum was generally characterized by these kinds of teaching methods.

Essentialism focused on cognitive and intellectual essentials - English, Mathematics, Science, History and a foreign language (Ornstein & Hunkins 1993). Both past and contemporary knowledge were acceptable to Essentialism unlike Perennialism, which focused on past knowledge (Olivia 1992, cited in Van Loggerenberg 2001). Van Loggerenberg (2001) goes on to emphasize the behaviouristic nature of Essentialism which encouraged a passivity of students and the centrality of the teacher. As mentioned above, the traditional science curriculum focused on imparting knowledge to students and was premised on behaviorism. Thus, behaviourism is the common link between Essentialism and the traditional science curriculum. The corresponding teaching methods included, amongst others, "programmed instruction, drill, standardized tests, (and) behavioural objectives..." (Olivia 1992, cited in Van Loggerenberg 2001:5).

The foregoing discussions on Essentialism and Perennialism emphasize the subject and teacher focus of the traditional science curriculum. There was also a quasi student-centred approach to the traditional science curriculum with the apparent focus on the scientific method. Progressivism, which is a more contemporary philosophy compared to Perennialism and Essentialism, placed more emphasis on the learner as compared to content. Progressivism also endorsed the scientific method, as did the conception of traditional science in the CUMSA Discussion Document (DOE 1992a). Sadly though, the scientific method was not pursued in its true sense in traditional science. Scientific method was confined to practical work where the process of investigation and the results were predetermined, as outlined in the Syllabus for Physical Science (DOE 1994). Ornstein & Hunkins (1998:3) believe that in the pursuit of making the traditional curriculum more scientific, "teaching and learning (was reduced) to precise behaviours with corresponding activities that could be measured." The true student-centred approach to science is outlined below in the discussion on the Natural Sciences in the context of transformational OBE.

Before dwelling on the underpinning learning theories of transformational OBE, it is imperative to understand the political and social circumstances in which OBE was introduced in South Africa. This background lends itself to the underpinning learning theories of OBE. Motala (1997) asserts that "the genesis of OBE is part of the history of a struggle for an entirely new education system. It arose…in the liberation movement in civil society from the beginning of the nineties…there was a strident criticism of the failure of the racist, fragmentary, incoherent, dead-end forms of education which characterized apartheid education." Accordingly, the aim of C2005 (even in its most recent form), as described by Mahomed (2001:79) is: "the replacement of the apartheid/colonial curriculum with a curriculum that is likely to develop citizens who can participate effectively in social, political, and economic development processes for an integrated, democratic and just country." But how does this translate into a learning theory?

It is apparent that the liberation movement spawned the concept of outcomes as envisioned in OBE. Jansen (1997) maintains that in South Africa, OBE was inspired by the competency debates in Australia and New Zealand. These competency debates were very appealing to the National Training Board (NTB) in South Africa and surfaced in their policy documents like the NTB Initiative. The concept of competencies was simultaneously gaining popularity in the pursuit of integrating education and training in South Africa, and subsequently featured in the National Qualifications Framework (NQF). Later on (1997) the concept of competencies evolved into outcomes in the Department of Education. Parker (1997) confirms this training paradigm origin of OBE in South Africa, and he cautions us against an exclusive focus on skills as is common in industry. Nonetheless, what are the underpinning learning theories of OBE?

Jansen (1997) lists a variety of learning theories that informed OBE, including behavioural psychology, which was also profoundly influential on the traditional curriculum in South Africa as described above. Other influential theories proposed by Jansen (1997) include Ralph Tyler's curriculum objectives and the mastery learning approach of Benjamin Bloom.

Yet another learning theory that has strong influence on the South African version of OBE, i.e. C2005, is Constructivism. Indeed, OBE in South Africa is fingerprinted by Constructivist principles. Not only does the Lifelong Learning for Education and Training Document (DOE 1996a) openly endorse Constructivism, but latter's fundamental principle of learners constructing their own knowledge is encouraged in the nature of the teaching methodologies proposed. For example, "activity based learning where learners explore ideas and approaches to learning and practice skills," is encouraged in the Lifelong Learning for Education and Training Document (DOE 1996a:46).

The origins of learner-centredness, as espoused in Constructivism, date back to the onset of Progressivism, which subordinated subject content to the learner. Van Loggerenberg (2001) affirms that Progressivism emphasized how to think and not what to think. One can then conclude with some certainty that the educational philosophy that underpinned outcomes-based education was indeed Progressivist in nature as well. In the discussions that follow on the nature of C2005, the above learning theories will manifest themselves in various ways.

The Discussion Document of C2005 (DOE 1997a:133) emphasizes the investigative nature of the Natural Sciences where "learners should be active participants in the learning process in order to build a meaningful understanding of concepts which they can apply in their lives." C2005 is premised on an OBE learning paradigm. According to Chisholm et al (2000:23), "the basic principles of OBE are positively defined as a results based, learner-centred, (with an) experiential and integrated approach, using new methods such as group work and continuous assessment…" In such a system, a "learner's progress is based on demonstrated achievement of a predetermined outcome" (unofficial document of the DOE 1996, cited in Goolam 1997:1). Outcomes, in turn, are either defined as critical (crosscutting) or specific (linked to particular subjects or learning areas), and are discussed below.

It is important at this stage to distinguish between the three different kinds of OBE, namely, traditional, transitional and transformational OBE. Spady (1994, cited in Killen 1999:2) states that:

> *"traditional outcomes are grounded primarily in subject matter content…these demonstrations are not generalizable across other areas of the curriculum or other performance contexts, school is the only place where they are typically performed…*

(for) transitional outcomes demonstrations are relatively complex... are generalizable across content areas and require substantial degrees of integration, synthesis, and functional application, thereby encouraging interdisciplinary approaches to developing the outcomes.

at the highest level, transformational outcomes require the highest degrees of ownership, integration, synthesis, and functional application of prior learning because they must respond to the complexity of real life performances."

It is transformational OBE that appeals to South Africa, and therefore transformational outcomes suffuse C2005. It is also the transformational outcomes that appeal to the discipline of science and technology as they lend themselves most to "responding to the complexity of real life performances" as envisaged by Spady (1994, cited in Killen 1999:2) above. The discussion now shifts to a comparison of the goals of the traditional curriculum with transformational OBE in science.

4.2.2. <u>Goals</u>

According to Ornstein & Hunkins (1998:272), "goals are statements of purpose with some outcome in mind...(they) suggest intended destinations, they do not specifically denote particular learning." The literature pertaining to the traditional curriculum [The CUMSA Discussion Document (DOE 1992a); CUMSA - abbreviated with Questions and Answers (DOE 1992b); The ERS Discussion Document (DOE 1992c); The ERS, Questions and Answers (DOE 1992d); A Subject Policy for Physical Science (DOE 1993); and The Syllabus for Physical Science (Higher and Standard Grade) Standards 9 and 10 (DOE 1994)] are silent on goal statements and tend to focus on aims.

Aims are more open-ended statements and form the basis for goals that are either long or medium term in nature, not immediate. The traditional Syllabus for Physical Science outlined the following general or broad aims of the discipline:

- "to provide pupils with the necessary subject knowledge and comprehension, i.e. knowledge of the subject as science and as technology;
- to develop in pupils the necessary skills, techniques and methods of science, such as the handling of certain apparatus, the techniques of measuring, etc.;
- to develop in pupils the desirable scientific attitudes, such as interest in natural phenomena, desire for knowledge, critical thinking etc.

- to introduce pupils to the scientific explanation of phenomena;
- to introduce pupils to the use of scientific language and terminology; and
- to introduce pupils to the applications of science in industry and in everyday life"

(DOE 1994:3).

The general or broad aims of the Syllabus for Physical Science (DOE 1994) are echoed in the Interim Core Syllabus for General Science, Standards 5, 6 and 7 (DOE 1995). The emphases in the General Science Syllabus were pitched at a lower level of ability as this subject was offered as a precursor to the Physical and Biological Sciences. The General Science Syllabus emphases related to the acquisition of knowledge, development and use of an appropriate vocabulary, effective use of the scientific method, and the appreciation of science and creation, and their implications for our way of life.

The most striking feature about the aims of the traditional Physical and General Science syllabi, as presented above, is the conception that the world of science is separate from the world of the student, i.e. it ignores the fact that students are sources of subject knowledge, skills and attitudes, and this can be a critical starting point in the construction of new knowledge, and the development of new skills and attitudes.

Another interesting feature of the two traditional syllabi was that technology had not yet acquired subject status. However, there were deliberate attempts to raise awareness in students of the importance of technology as can be gleaned from some of the aims of the Syllabus for Physical Science (DOE 1994). For example, the first aim alludes to the importance of providing students with the necessary subject knowledge in science and technology. The sixth aim also lends itself to technology as students were introduced to the applications of science industry and in everyday life. This sixth aim has a semblance of transformational OBE with its focus on everyday life applications of knowledge. While there was a tendency towards embracing technology in the traditional science syllabi, there was no deliberate attempt to extend the concept to include the science-society movement.

According to the Discussion Document of C2005, it can be deduced that the goals, or rationale, for the Natural Sciences learning area, which is a combination of Physical, Life and Earth Sciences, are based on:

"The development of appropriate skills, knowledge and attitudes and an understanding of the principles and processes of the Natural Sciences...

- *(to) enable learners to make sense of their natural world;*
- *(to) contribute to the development of responsible, sensitive and scientifically literate citizens who can critically debate scientific issues and participate in an informed way in democratic decision-making processes;*
- *for conserving, managing, developing and utilizing natural resources to ensure the survival local and global environments; and*
- *(to) contribute to the creation and shaping of work opportunities"*

(DOE 1997a:133).

This conception of the Natural Sciences, within the framework of C2005, differs markedly from the traditional conception of the Natural Sciences. Within the framework of C2005, the worlds of science and the student are inextricably linked; i.e. students are also sources of subject knowledge, skills and attitudes. This interdependence between the students and science is critical in the construction of new knowledge, and the development of new skills and attitudes.

The glaring addition of Technology as an independent subject or learning area in the Further Education and Training Band of the NQF (grades 10 to 12) within C2005, represents a gigantic leap in curriculum development for South Africa. Prior to 1998, there were attempts to introduce Technology into the syllabus. Indeed, one of the revisions of the curriculum proposed in the CUMSA Discussion Document (DOE 1992a) was the introduction of technology as one of the new subjects. The purpose of introducing Technology into the curriculum was because of the emphasis on application value of the content. The conception of technology presented in the CUMSA - abbreviated with Questions and Answers – document is impressive:

"What does the subject Technology comprise? In Technology the emphasis falls on the learners' purposeful mastery and creative use of knowledge and skills regarding the products, processes and methods of approach, in order to control the environment (better). Processes in this connection include problem identification, design, execution and evaluation. Technological knowledge, skills and attitudes are also addressed as far as possible in other subjects. What is taught in the other subjects is also coordinated and integrated with specific technological knowledge, skills and attitudes into the subject Technology"

(DOE 1992b:7).

Ironically, the CUMSA - abbreviated with Questions and Answers - document (DOE 1992b) declared that subjects like writing, technical orientation, home economics and wood-/metalwork formed the components of the new subject, Technology, in Grades 1 to 9. As outlined in chapter two, and particularly emphasized by the T2005 Gauteng Task Team Report (Rogan et al 1998), technology cannot be narrowly defined vis-à-vis' technical subjects like woodwork (see sub-section 2.2. pp.12-15). The T2005 Gauteng Task Team (ibid) also designed technology materials for Grade I learners and piloted them in 30 Gauteng schools. However, technology has never been successfully mainstreamed in South Africa.

4.2.3. Objectives/Outcomes

The foregoing discussion on goals introduced the concept as statements of purpose that do not denote particular learning. Goals were also described as long to medium term in nature. Objectives and outcomes tend to be more focused on learning units and they are short term in nature.

An interesting similarity between the two paradigms is the focus on objectives in the traditional curriculum and the focus on outcomes in Outcomes-Based Education. An interesting finding in the Syllabus for Physical Science (DOE 1994:3) states explicitly that "the teacher may specify the objectives for each topic and lesson. However, suggested objectives are *provided* for the guidance of teachers." Thus, for both OBE and the traditional science curriculum, predetermined learning outcomes and objectives were evident.

There is however a distinct difference between objectives and outcomes. Ornstein & Hunkins (1998:276) defined a behavioral objective as "a precise statement of outcomes in terms of observable behaviour expected of students after instruction." There was a deliberate preoccupation with content or knowledge in the traditional science syllabus, almost to the extent that it eclipsed the skills component, and the values component was rare. The following objectives of the Standard 9 traditional Syllabus for Physical Science, for the topic Light, accentuate the deliberate preoccupation with content:

"Pupils should be able to:

(1) define: wavelength,...

(2) state: the principle of superposition;

(3) describe: transverse waves,...

(4) explain the following properties if light: reflection; ...

(5) interpret equations...

(6) perform calculations

(7) contrast transverse waves with longitudinal waves"

(DOE 1994:6).

Although there are several experiments that can be used to stimulate understanding of the above concepts, the traditional syllabus prescribes the demonstration of these experiments rather than allowing students to experiment independently. There was no real notion of experimenting and/or discovering scientific principles. Textbooks prescribed in a recipe format the 'experimental method,' and provided the answers to the so-called discovery questions immediately after the experiment. This is yet another illustration of how the traditional curriculum perceived the world of science as separate from the world of the student. Moreover, it is clear from the above objectives that if one has the ability to commit information to memory then they will be successful. There is a distinct shift with the transition to OBE where:

"Outcomes are what learners can actually do with what they know and have learned – they are the tangible application of what has been learned. This means that outcomes are actions and performances that embody and reflect learner competence in using content, information, ideas, and tools successfully"

(Spady 1994:2).

This preoccupation with OBE represents a quantum leap for education in South Africa as the exclusive emphasis on knowing, as was customary in the past, is now transcended by the demonstrated application of the knowledge, skills and/or values.

As mentioned above, there are two types of outcomes in C2005, namely critical and specific outcomes. The Discussion Document of C2005 defined the critical outcomes as:

"broad, generic, cross curricular outcomes which underpin the Constitution (of South Africa)...These (critical) outcomes will ensure that learners will gain the skills, knowledge and values that will allow them to contribute to their own success as well as to the success of their family, community and the nation as a whole"

(DOE 1997a:10).

There are seven critical outcomes proposed by the South African Qualifications Authority (SAQA). Accordingly, learners will:

1. *Identify and solve problems and make decisions using critical and creative thinking.*
2. *Work effectively with others as members of a team, group, organization and community.*
3. *Organize and manage themselves and their activities responsibly and effectively.*
4. *Collect, analyze and critically evaluate information.*
5. *Communicate effectively using visual, symbolic, and or language skills in various modes.*
6. *Use science and technology effectively and critically showing responsibility towards the environments and the health of others.*
7. *Demonstrate an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation"*

(DOE 1997a:10).

As mentioned in chapter one, critical outcomes 1; 4; 6 and 7, lend themselves directly to this study as they are intimately linked to science and technology, and the demonstration of specific outcomes in science and technology that are subsumed within critical outcome 6 will be examined in chapter five.

Specific outcomes "refer to the specification of what learners are able to do at the end of a learning experience. This includes skills, knowledge and values which inform the demonstration of the achievement of an outcome or a set of outcomes" as per the Discussion Document of C2005 (DOE 1997a:12). The specific outcomes for the Natural Sciences as outlined in the Discussion Document of C2005 (ibid:134) include:

- *Use process skills to investigate phenomena related to the Natural Sciences.*
- *Demonstrate an understanding of concepts and principles, and acquired knowledge in the Natural Sciences.*
- *Apply scientific knowledge and skills to problems in innovative ways.*
- *Demonstrate an understanding of how scientific knowledge and skills contribute to the management, development and utilization of natural and other resources.*
- *Use scientific knowledge and skills to support responsible decision-making.*
- *Demonstrate knowledge and understanding of the relationship between science and culture.*
- *Demonstrate an understanding of the changing and contested nature of knowledge in the Natural Sciences.*

- *Demonstrate an understanding of the interaction between the Natural Sciences and socio-economic development.*

While there is a focus on concepts and principles as with the traditional curriculum, these outcomes add new dimensions to the Natural Sciences. For example, (1) the application of knowledge and skills in innovative ways which intimates an appreciation of the learner's way of using science, (2) an appreciation of the changing nature of information, not perceiving science as static as was the case with the traditional science curriculum, and (3) the interaction of science with culture, and socio-economic development which was not discernible in the traditional curriculum.

Specific outcomes for technology as outlined the Discussion Document of C2005 (DOE 1997a:84) focused on Learners being able to:

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

The specific outcomes as outlined above resonate with the vision of transformational OBE described above as they "require the highest degrees of ownership, integration, synthesis, and functional application of prior learning because they must respond to the complexity of real life performances" (Spady 1994, cited in Killen 1999:2)

The issues raised above about objectives and outcomes beg the question about the nature of the content in each of these types of curricula. A discussion of curriculum content follows.

4.2.4. Content

The CUMSA Discussion Document (DOE 1992a:35) outlined the general characteristics of the traditional curriculum: "In essence, the junior and senior primary, and junior secondary phases were general-formative in nature, and the senior secondary phase of education is either generally oriented, vocationally oriented or vocational education..."

The generally oriented curricula were concerned with the unlocking and mastery of knowledge. Application of knowledge was not important but constituted the point of departure in these subjects. Subjects in this category of generally oriented curricula included Languages (English and Afrikaans were compulsory, additional languages were also allowable), Mathematics, Physical Science, Biology, History, Economics, Geography, and Biblical Studies. As a result of the deliberate focus on mastery of knowledge, generally-oriented curricula were characterized by a content-laden syllabus.

The vocationally oriented group essentially followed a curriculum that combined general and vocational subjects. The emphasis was on the exposition of knowledge, the inculcation of values and attitudes, as well as the transmission of skills that have a more direct practical value in one or more broad vocational directions.

Vocational education entailed a specific instructional program containing vocational subjects with a strong practically oriented component and the tuition was offered at an institution equipped for vocational education. Vocationally oriented subjects were primarily concerned with the application of knowledge and skills in the general sphere of life. "Vocational education subjects are those which have as their point of departure a broad vocational field and are aimed at the mastery and application of knowledge, skills and attitudes within a specific vocation. Broad vocational fields included Engineering, Business, Arts, Agriculture, Utility Industries, and Social Services," according to the CUMSA Discussion Document (DOE 1992a:39).

In the Syllabus for Physical Science (DOE 1994), the traditional science syllabus was presented as a combination of content, practical work and objectives. For example, if the objective was that pupils should be able to define wavelength, then the corresponding practical work entailed the use of a pendulum to explain the concept, and the theory was a revision of previous work on waves to revise terminology. The use of simplifications like conceptual models were encouraged, teachers were advised to stress that these models were not intended to serve as fully acceptable scientific explanations.

The main aims of practical work were:

a) to help pupils understand the fundamental role played by experiment and observation in establishing and extending the body of scientific knowledge;
b) to facilitate learning and understanding of facts and principles;
c) to give pupils opportunities of making simple discoveries of their own;
d) to provide experience of elementary measuring techniques, and acquaintance with some of the measuring instruments in common use; and
e) to give practice in recording and treatment of observations, the drawing of appropriate conclusions and the presentation of results

(DOE 1994:5).

As stated above, despite the apparent emphasis on practical work, skills and values, there was a deliberate preoccupation with content or knowledge in the traditional science syllabus, almost to the extent that it eclipsed practical work. Although the use of practical work was also encouraged in the traditional science curriculum, it was rarely assessed in the Grade 12 (matric) examination. Practical work was never regarded as important as the content/theory component of the examinations.

One of the principal reasons for the paradigm shift in South African education was to make the transition from "content to outcomes" as emphasized in Outcomes-Based Education in South Africa, Background Information for Educators - Draft (DOE 1997b:5). According to Chisholm et al (2000:22), content was initially de-emphasized in the new curriculum. There is a deliberate silence in the C2005 documents on the nature of the content that must be pursued. This silence was intentional as the specification of content was seen as prescriptive within the OBE paradigm. The selection of content or associated concepts is the responsibility of the teacher. However, this approach presupposes a satisfactory information and conceptual knowledge within all teachers, and that is far from the reality in South Africa as outlined in the Taylor & Vinjevold (1999) Report on the President's Education Initiative (PEI): Getting Learning Right. "One of the most consistent findings across a number of PEI projects pointed to teachers' low levels of conceptual knowledge, their poor grasp of their subjects and the range of errors made in the content and concepts presented in their lessons" (Taylor & Vinjevold 1999:139).

Moreover, Malcolm (2000, cited in Chisholm et al 2000:38) stated that "questions of content and conceptual understanding are troublesome in outcomes-based education... This has resulted in the recognition that teachers require greater guidance and support in content specification. This has happened in one of two ways: either by stipulating finer and finer levels of outcomes or by conceptual coherence through guidance on inputs...C2005 has done mainly the former."

Jeevananthan (1999:52) advises that "in spite of the fact that content is not prioritized in the OBE system, it is not true that content is incidental and therefore unimportant...In the classroom, subjects do not look through and beyond content to the attainment of skills, values, attitudes, and competences. They interact with the content...in the process of achieving desired outcomes." It seems as though the advice of Jevananthan (1999) was heeded by Chisholm et al (2001a) in the construction of the Draft Revised NCS for Grades R-9. Indeed, the assessment standards of the NCS intimate content or conceptual knowledge. For example, in the Natural Sciences Learning Area at Grade 7 level, the learning outcome pertaining to the development and application of scientific knowledge and understanding is assessed when a learner "describes the structure of the earth, and in particular, its crust in relation to the biosphere" (Chisholm et al 2001b:62).

The content-laden focus in the traditional curriculum and the apparent lack thereof in the new OBE curriculum hint at the nature of teaching strategies or methodologies that each of them might pursue. A discussion of these teaching strategies follows.

4.2.5. <u>Teaching Strategies/Methodologies</u>

According to the Report on the PEI: Getting Learning Right, which quotes a variety of corroborating sources including the National Education Policy Investigation (NEPI), Teacher Education Report (1992) and the African National Congress Policy Framework for Education and Training (1994):

> *"...the doctrine of fundamental pedagogics has had profoundly detrimental effects on the teachers' thinking and practice...Fundamental pedagogics is based on premises which can be interpreted as authoritarian (for example, the teacher, as knowing adult, leads the child to maturity)...."*
>
> Taylor & Vinjevold (1999:132).

It is this philosophy of fundamental pedagogics that prompted some of the following striking changes in the teaching and learning features of the curriculum in South Africa, as outlined in the C2005 Booklet, Lifelong Learning for the 21st Century:

Traditional Curriculum	OBE Curriculum
Passive learners	Active learners
Rote learning	Critical Thinking
Textbook/worksheet bound and teacher centred.	Learner-centred, teacher is facilitator; teacher constantly uses group work and teamwork to consolidate the new approach.
Teachers responsible for learning; motivation dependent on personality of teacher	Learners take responsibility for learning, pupils motivated by constant feedback and affirmation of their worth.
Emphasis on what the teacher hopes to achieve	Emphasis on outcomes – what the learner becomes and understands.

Adapted from C2005 Booklet, Lifelong learning for the 21st century (DOE 1997c:6)

Table 4.1. Differences between the Traditional and New Curriculum

The traditional approach to teaching can (as expressed in Table 4.1) also be described as content-based programming. Killen (1999:9) defines this approach as "an exclusive focus on covering the curriculum by teaching a predetermined amount of content in each time period. Very often, the content that is taught will be linked very closely to a subject-based textbook..." The teaching strategy associated with such content-based programming was predominantly a chalk and talk method, and a subsequent rote learning of information by learners. C2005 offers more learner-centred teaching strategies.

According to the document titled Outcomes-Based Education in South Africa, Background Information for Educators – Draft, the transition to OBE in South Africa signals a change "from a talk and chalk – rote learning system to being flexible and (adapting) to learner needs and different learning styles and learning preferences" (DOE 1997b:42). The Lifelong Learning for Education and Training Document characterized the new transformational OBE teaching methodology as:

- Change in the perception of educators from dispensers of knowledge to active participants or guides on the side or facilitators of learning;
- Activity based learning where learners explore ideas and approaches to learning and practice skills;
- Co-operative as well as individual learning contexts so that learners can develop skills of working collaboratively in a group, and individually, and the ability to recognise when each mode is appropriate;
- Formative assessment, so that the processes and developmental nature of learning, as well as products are seen as important;
- The setting of tasks that integrate theory and practice, and manual and mental learning where practicable, and which link classroom learning to the broader society in which it is located"

(DOE 1996a:46).

Botha and Hite (2000) present an interesting theory, proposed by Deming, that OBE places emphasis on outcomes at the expense of process. However, the process-oriented teaching and learning strategies of C2005 (described in Table 4.1. and listed above) defy this theory. According to Chisholm et al (2001a:18), "outcomes-based education considers the process of learning as important as the content. Both the method and the content of education are emphasized by spelling out the outcomes that need to be achieved at the end of the teaching and learning process."

In theory then, C2005 must be lauded; but, in practice we need to revisit the process deficits of C2005 alluded to by Botha and Hite (2000). Taylor & Vinjevold (1999) listed some of the challenges associated with implementing C2005. One of the principal challenges was the teachers' low levels of conceptual knowledge, which is a fundamental pre-requisite to satisfy the C2005 teaching strategies described above. Botha and Hite (2000) remind us that we need to improve the quality of teaching in our classrooms for OBE to be successful. Indeed, we do have the vision of what OBE classrooms should be like, but we need to facilitate the successful implementation of those ideas. Otherwise, "learners will fall by the wayside, or they will struggle to succeed if not assisted by a dedicated and competent teacher" (Botha and Hite 2000:139).

Equally important in the pursuit of successful OBE implementation in South Africa is developing and practising quality OBE assessment practices. Kotze (1999:31) correctly insists that "assessment is not a separate part of the learning experience." The assessment features of the traditional and OBE paradigms are described below.

4.2.6. Assessment Strategies

Rault-Smit (2001:5) maintains that the purpose of traditional assessment was "to report on what a learner had or had not done" and this now needs to change "to a system in which the purpose of assessment is to identify what a learner is doing, how the learner is doing, and how the learner can be supported in his/her learning." Another comparison drawn by Rault-Smit (2001) is that in the traditional curriculum, the educator tests pupils from a position of power whereas in OBE, educators and learners are partners in the assessment process. These transformations in assessment practices necessitated by the shift to OBE require corresponding shifts in the perceptions of educators.

In accordance with Rault-Smit's (2001) interpretation of traditional assessment focusing on what a learner had done or had not done, the traditional science curriculum emphasized summative assessment, and was characterized by mid-year and final examinations. These examinations were also high stakes activities as they determined whether or not learners progressed from one grade to another, or moved onto other levels of the education system. The external examinations in Standard 10 (Grade 12) were conducted at different levels, namely higher and standard grades, with the former being the more academically challenging. There was an emphasis on content in these examinations; but there were attempts, although rare, to include practical work. For example, according to the Syllabus for Physical Science (DOE 1994), the examinations were based on the syllabus content prescribed by the education authorities, but the principles involved in physics practicals were also examined in the theory papers. This culture of high priority summative examinations still prevails. "In South Africa, public examination results are the main performance indicators of schools. Schools with the highest number of passes are reported in the public media" (Botha and Hite 2000:134).

To satisfy the aspirations of OBE assessment as described by Rault-Smit (2001) above necessitates a formative and summative approach to assessment, as teachers must assess learners' progress continually. Formative assessment "is integrated throughout a learning experience" (Kotze 1999:31), it is on-going. Assessment in an OBE system enables both learners and teachers to determine whether learners are achieving the agreed outcomes or not. A variety of strategies are used to measure the proeess and product of learning, namely, "tests, essays, projects, and portfolios" as outlined in Outeomes-Based Education in South Africa, Background Information for Educators - Draft (DOE 1997b:41). Self or peer assessment may also be administered.

The complexity of C2005 resides, in part, in the plethora of new terms that have emerged with this new curriculum. An examination of the OBE terms in assessment will attest to the complexity of the vocabulary of OBE. Some of these terms include critical and specific outcomes, performance indicators, range statements, and assessment criteria.

As mentioned above, there are two types of outcomes in C2005, namely critical and specific outcomes, which were discussed above. Learning and teaching in OBE are directed at achieving these outcomes and performance indicators. The latter is a new concept and must be explained relative to its associated terms, namely assessment criteria and range statements. An example will be used to illustrate the relationship between the three terms. Consider the following specific outcome (SO) for the Natural Sciences. SO 8: Demonstrate knowledge and understanding of ethical issues, bias and inequities related to the Natural Sciences.

"The range statement indicates the scope, depth, level of complexity and parameters of the achievement. They also include indications of the critical areas of content, processes and context..." according to the Discussion Document of C2005 (DOE 1997a:12). For example, part of the range statement for the above SO 8 is:

"In developing their work, learners

- Brainstorm, discuss or read to identify an ethical issue of interest.
- Argue and reason about an issue with respect for different viewpoints..."(ibid:158).

"The assessment criteria provide evidence that the learner has achieved the specific outcome...The assessment criteria are broadly stated and do not themselves provide sufficient details of exactly what and how much learning marks an acceptable level of achievement of the outcome" (ibid:12). For example, the assessment criteria associated with the above SO 8 include:

"Learners show work in which:

- A variety of viewpoints are acknowledged.
- A variety of origins of bias and inequity are considered..." (ibid:158).

Performance indicators provide details of the content and processes that the learners should master, as well as details of the learning contexts in which the learner will be engaged. For example, in South Africa this could entail developing an understanding of the inequity and issues associated with not making the drug AZT available to pregnant women who are infected with HIV/AIDS.

Fortunately, the Draft Revised NCS for Grades R-9, in an attempt to streamline C2005, recommends only two main terms for assessment, namely learning outcomes and assessment standards. A learning outcome is a "description of what (knowledge, information, skills, attitudes and values) learners should know and be able to do at the end of a grade...(and) one learning outcome may cover more than one grade" (Chisholm et al 2001a:21). For example, a learning outcome in the Natural Sciences is: "the learner should be able to develop and use science process skills in a variety of settings" (Chisholm et al 2001b:18). "Assessment standards describe the level at which learners should demonstrate achievement of the learning outcome(s) and ways (depth and breadth) of demonstrating achievement. They are grade specific and...they embody knowledge, skills and values required to achieve the learning outcome (Chisholm et al 2001a:22). An example of an assessment standard for Grade 8, and linked to the above learning outcome, is: "illustrate the internal structure of the earth in a variety of ways, e.g. models, drawings" (Chisholm et al 2001b:57).

All the ramifications of the OBE assessment system have not been elaborated upon in detail. The idea was to provide a broad brushstroke overview of the changes to highlight the critical differences between traditional and OBE assessment. What can be discerned from this brief discussion on assessment is that traditional assessment will have to undergo significant change to accommodate the changes necessitated by OBE.

The foregoing discussions compared the traditional science curriculum and the new transformational outcomes based science curriculum with regard to underpinning learning theory; goals; objectives/outcomes; content; teaching strategies/methodologies; and assessment strategies. The discussion is intended to serve as a preamble to the analysis of the actual teaching and learning experiences of the students which follows. The theoretical framework of the traditional and transformational science curricula have changed dramatically as a result of the paradigm shift and it will be interesting to see if there were concomitant changes in the de facto teaching and learning practices.

4.3. The Teaching and Learning Experiences of the Students who experienced a Traditional Science Curriculum

This section illustrates and discusses the kinds of teaching and learning experiences of the students. (See Appendix 1 – Questionnaire – for related teaching and learning variables: 94-99, and 102-108, excluding 105). The discussions are informed by the comparison of the traditional and transformational outcomes-based paradigms described above. Thereafter, relationships that exist between different teaching and learning experiences are highlighted using graphics. For example, does a chalk and talk approach to teaching correspond with a memorizing of notes learning experience?

4.3.1. The Kinds of Teaching Experienced by the Students

Students were 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 were provided with for each of these kinds of teaching were: always; most times; a few times; and never. A frequency description will follow for each kind of teaching. Thereafter, the results will be discussed using selected elements of the comparison of the traditional and the transformational OBE paradigms that featured above in sub-section 4.2. (pp.74-94).

4.3.1.1 Mainly Chalk and Talk

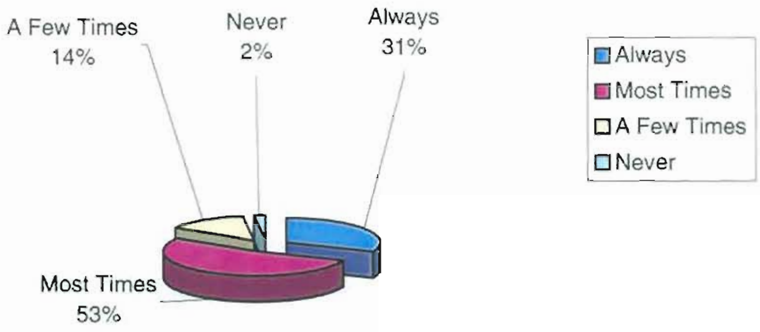

Figure 4.1. The Frequency with which Chalk and Talk featured as a Teaching Method

Chalk and talk was an extremely popular method of teaching amongst the students. 31 % of the students claimed that this was always the method of teaching, and 53 % stated that chalk and talk was used most times. A mere 14 % maintained that they were exposed a few times to the chalk and talk method, and just 2 % were never exposed to this method of teaching.

4.3.1.2 Use of Textbooks to Explain

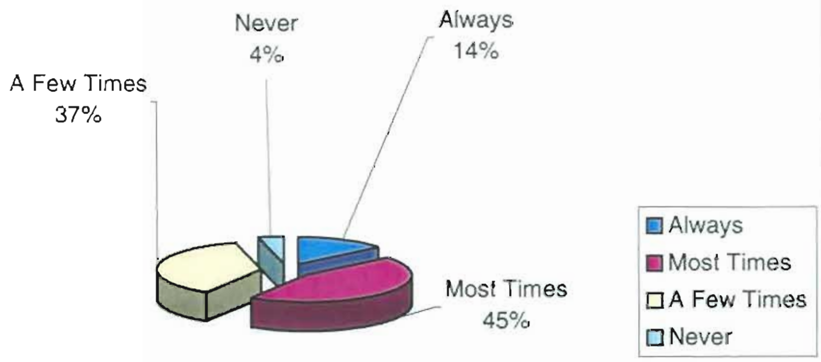

Figure 4.2. The Frequency with which Textbook Explanations were used as a Teaching Method

Textbook explanations were not as popular as chalk and talk, but it did feature quite often in the teaching practices experienced by the students. 14 % of the students declared that they always experienced this kind of teaching, 45 % experienced it most times, 37 % a few times, and 4 % were never exposed to this kind of teaching.

4.3.1.3. Questions and Answers

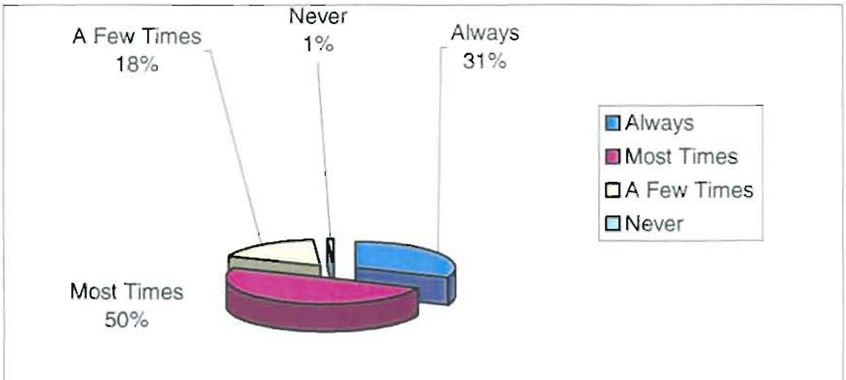

Figure 4.3. The Frequency with which Questioning was used as a Teaching Method

The questions and answers approach to teaching was as popular a teaching method as chalk and talk. 31 % of the students asserted that they always experienced this kind of teaching, 50 % experienced it most times, 18 % a few times and 1 % were never exposed to this kind of teaching.

4.3.1.4. Problem Solving

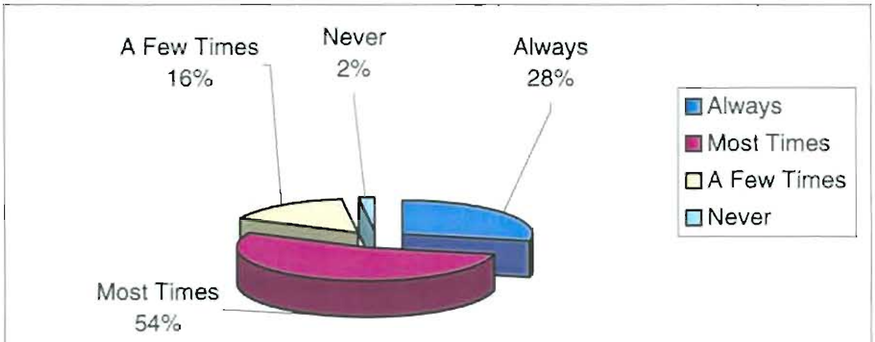

Figure 4.4. The Frequency with which Problem Solving was used as a Teaching Method

Problem solving also featured conspicuously as a common method of teaching amongst students. There appears to be a clustering of scores for the three most common types of teaching that students were exposed to. These common types in order of decreasing popularity, albeit by small margins, were chalk and talk, questions and answers and problem solving. The frequency counts for problem solving reflect that 28 % of the students declared that they always experienced problem solving as a method of teaching, 53 % experienced it most times, 16 % a few times and 2 % were never exposed to this kind of teaching.

4.3.1.5. <u>Science Experiments</u>

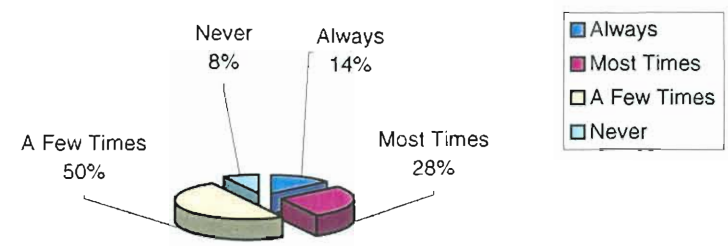

Figure 4.5. The Frequency with which Science Experiments were used as a Teaching Method

Science experiments were less popular than all the teaching methods discussed above. 14 % of the students declared that they always used science experiments as a method of teaching, 28 % experienced it most times, 50 % a few times and 8 % were never exposed to this kind of teaching.

4.3.1.6. <u>Working in Small Groups</u>

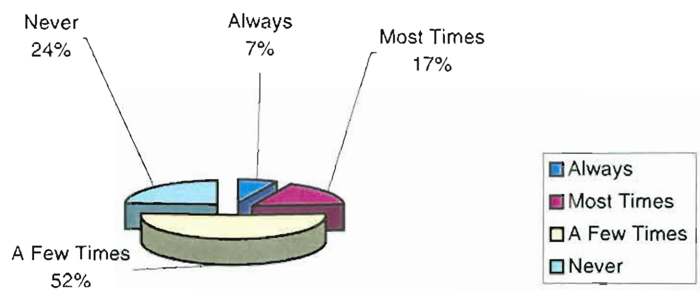

Figure 4.6. The Frequency with which Groupwork was used as a Teaching Method

This method of teaching was the least popular of all methods. 7 % of the students declared that they always used group work as a method of teaching, 17 % experienced it most times, 51 % a few times and 24 % were never exposed to this kind of teaching.

4.3.1.7. <u>Other Teaching Methods</u>

There were no meaningful responses to this alternative. Two students listed the use of the overhead projector as a method of teaching, but the overhead projector is a teaching resource not a teaching method.

4.3.1.8. Summary of the Distribution of Teaching Frequencies experienced by Traditional Science Students

To compare the frequency of the different teaching experiences of the students, some changes to the frequency descriptors were necessary. The frequency descriptors were combined as follows: (1) Always and Most Times were combined into the category titled Often; and (2) A Few Times and Never were combined into the category titled Seldom. Figure 4.7. illustrates the frequencies of these new descriptors.

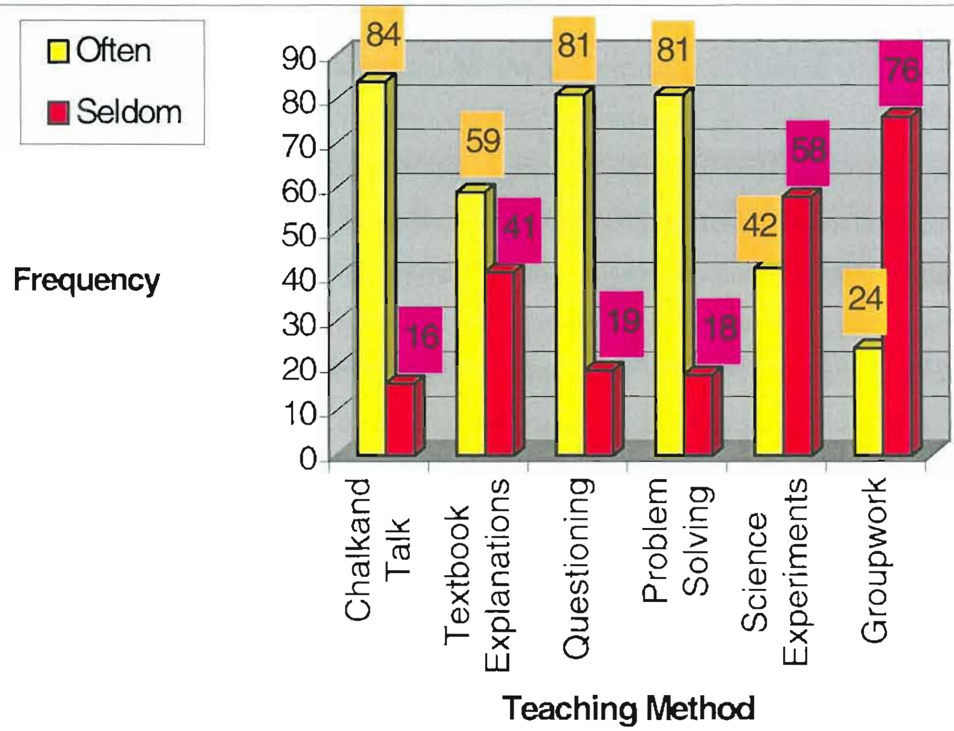

Figure 4.7. Summary of Frequency of Teaching Methods

The above findings are not surprising at all. If anything, the findings conform to the practices of teaching envisaged by the traditional curriculum. As discussed above (see sub-section 4.2. pp.74-94), the teacher is the central figure in the traditional approach to teaching science. Therefore, it is not startling that chalk and talk was the most popular kind of teaching that was experienced by the students.

The teaching method of questions and answers was the second most popular method of teaching. Once again the centrality of the teacher in the classroom situation is demonstrated in this finding. When the teacher simply posed a repertoire of questions, for which the correct answers were only known by the teacher, it was a way of shaping the thinking of the students and not permitting them the freedom of critical thinking as envisaged by OBE.

Problem solving emerged as the third most popular kind of teaching experienced by the students. This finding is somewhat inconsistent with the traditional science curriculum teaching methodology, which emphasized rote learning, and sometimes solutions to problems were also learned by rote. It must be noted that all the teachers who taught the traditional science curriculum cannot be painted with the same brush. Therefore, the coexistence of teachers who emphasized problem solving skills and critical thinking led to the above result.

Textbooks were often used as a method of purveying the 'truths' of science in the traditional curriculum. Therefore, it is not astonishing that textbooks were moderately popular as the fourth most popular method of teaching. Van Loggerenberg (2001) emphasized that traditional science was characterized by an overwhelming emphasis on a highly academic curriculum, which was content-laden. As textbooks were the primary source of content, their use was widespread. Hence, the moderate popularity of their use is seen in this cohort of students.

The lack of emphasis on science experiments as a teaching method is possibly because of the distinct separation of the theory and practical components of the traditional science curriculum. Even the examinations for practical work were separated from the theory papers although the concepts inherent in the practical work could be examined in the theory papers. Hence, there was an artificial separation of the theory and practical components of the syllabus.

Group work was the least popular method of teaching. This is typical of the traditional curriculum, which was not student-centred. Cooperative and activity based learning contexts were not consistent with the traditional curriculum. The traditional approach suppressed individual expression, and did not see learner contributions as supplementary to the body of knowledge in the syllabus. Also, teachers were not au fait with such a teaching methodology. Hence, it was remarkably unpopular.

The kinds of teaching experienced by the students, hints at the nature of their learning experiences. A discussion of the learning experiences of the students follows.

4.3.2. The Kinds of Learning Experienced by the Students

Students were 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 of their own ideas to understand new information;
f) Relate physics to real life; and
g) Other methods.

The frequency descriptors which students were provided with for each of these kinds of learning were: always; most times: a few times; and never. A frequency description will follow for each kind of learning. Thereafter, the results will be discussed using selected elements of the comparison of the traditional and the transformational OBE paradigms that featured above in sub-section 4.2 (pp.74-94).

4.3.2.1. Memorize notes and equations

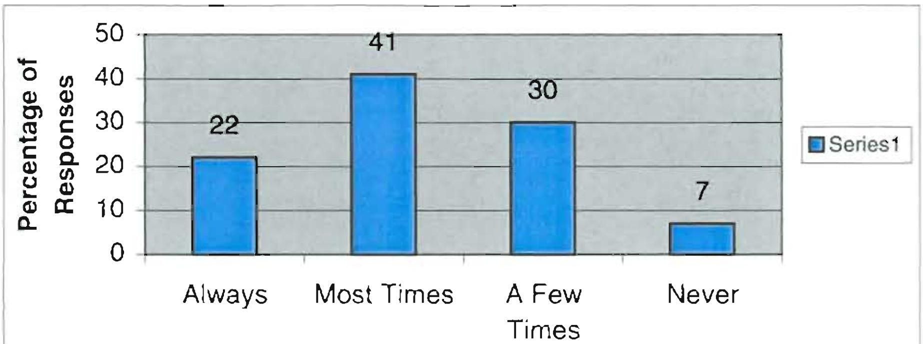

Figure 4.8. The Frequency with which Memorization was used as a Learning Method

Unexpectedly, the memorization of notes and equations did not show similar high frequencies as did its teaching methodology ally, chalk and talk. 22 % of the students claimed that they always experienced this kind of learning, 41 % experienced it most times, 30 % a few times, and 7 % were never exposed to this kind of learning.

4.3.2.2. Solve Problems using Numbers Only

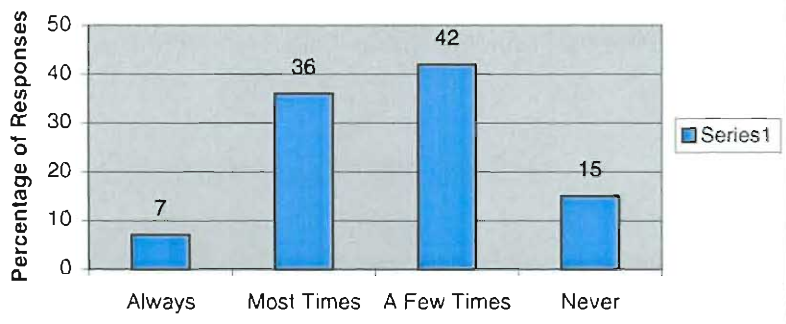

Figure 4.9. The Frequency with which students solved problems usings Numbers Only

This was the least popular method of teaching. The frequency counts for problem solving exclusively with numbers reflect that a mere 7 % of the students declared that they always used this method of learning, 36 % experienced it most times, 42 % a few times and 15 % never used this kind of learning.

4.3.2.3. Solve Problems using Concepts and Principles

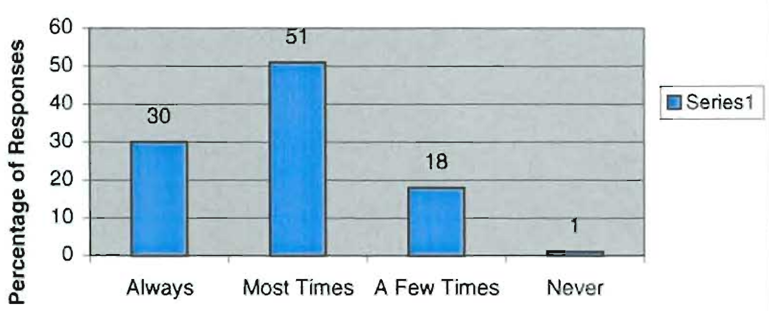

Figure 4.10. The Frequency with which students solved problems using Concepts and Principles

The use of concepts and principles to solve problems represents a higher order of understanding than simply inserting figures into equations. It was therefore very encouraging to note that this higher order level of learning was more frequently in use amongst the students. 30% of the students claimed that this was always the method of learning in use, and 51 % stated that concepts and principles were used most times. 18 % maintained that they used this method a few times, and just 1 % was never exposed to this method of learning.

4.3.2.4. Solve Problems using Numbers, Concepts and Principles

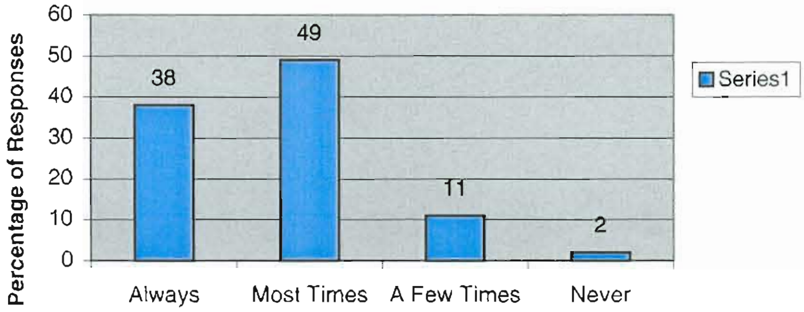

Figure 4.11. The Frequency with which students solved problems using Numbers, Concepts and Principles

This was the most popular method of learning that the students claimed to have used. This category is actually a conflation of b) and c) above and one would therefore expect a combined result for this type of learning, but that was not the case. 37% of the students maintained that this was always the method of learning in use, and 49 % stated that concepts and principles used most times. A mere 11 % declared that they used this method a few times, and 2 % were never exposed to this method of learning.

4.3.2.5. Use of their own ideas to Solve Problems

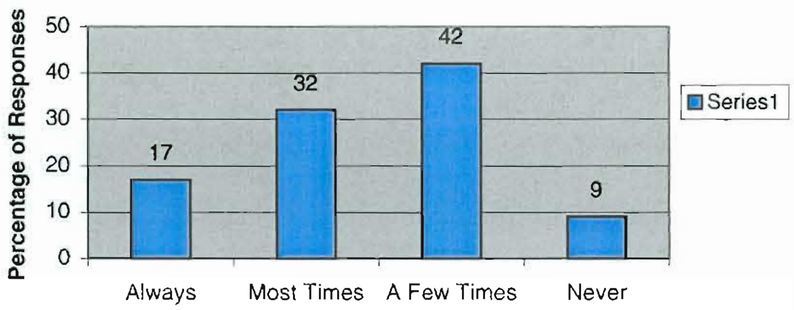

Figure 4.12. The Frequency with which students solved problems using their Own Ideas to Understand New Information

This method of learning was also unpopular with just 17 % of the students using it always, 32 % using it most times, 42 % using it a few times and 9 % never using it.

4.3.2.6. Relate Physics to Real Life Situations

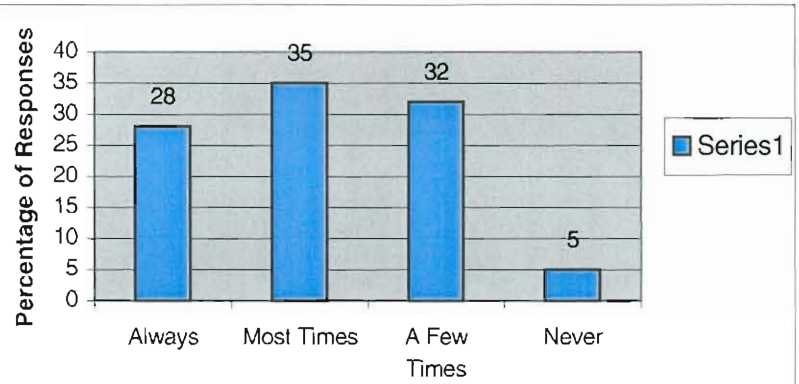

Figure 4.13. The Frequency with which students solved problems by Relating Physics to Real Life Situations

This method of learning was moderately popular with 28 % experiencing it always, 35 % using it most times, 32 % a few times and 5 % never used this method of learning.

4.3.2.7. Other Methods

There were no responses to this sub-question.

4.3.2.8. Summary of the Distribution of Learning Frequencies Relative to the Traditional Paradigm of Science Learning

To compare the frequency of all the different learning experiences of the students simultaneously, some changes to the frequency descriptors were necessary. The frequency descriptors were combined as follows: (1) Always and Most Times were combined into the category titled Often; and (2) A Few Times and Never were combined into the category titled Seldom. Figure 4.14. illustrates the frequencies of these new descriptors.

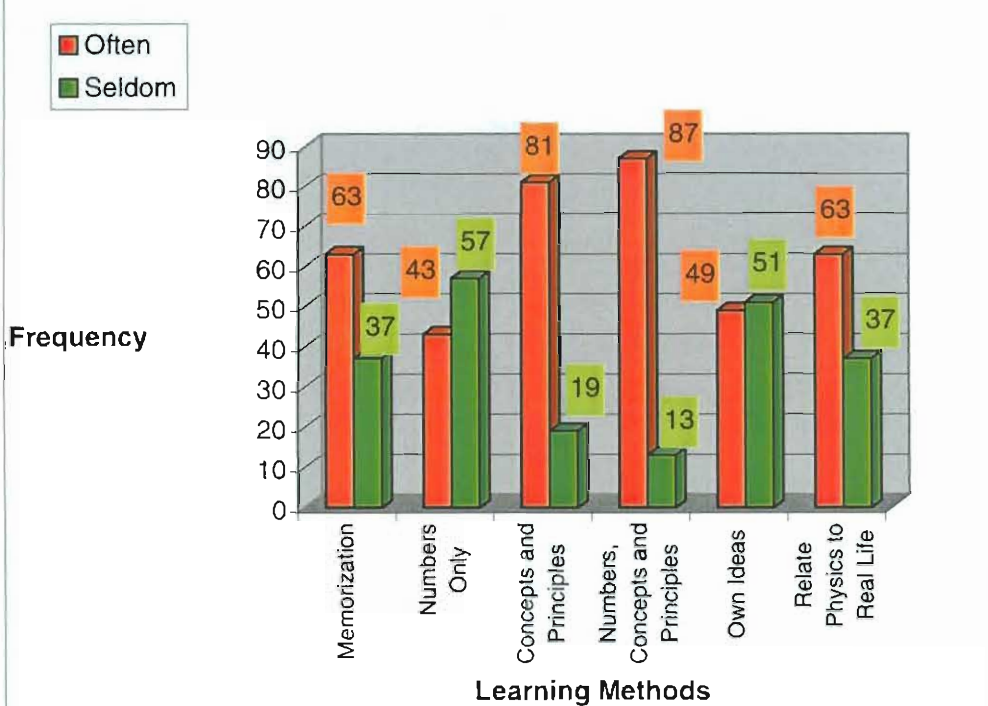

Figure 4.14. Summary of Frequency of Learning Methods

There is a striking disconnect between the learning and teaching methods that were experienced most frequently by the students. As chalk and talk was the most frequent teaching method, one would expect a corresponding learning method like memorization, or the mindless insertion of numbers into equations, to feature as the most frequent teaching method. That is not the case. Lower cognitive order types of learning like memorization (rote learning), and the exclusive use of numbers to solve problems, did not feature with great frequency.

The distribution of learning method frequencies was most interesting with the most popular method being the use of numbers, concepts and principles. This learning method is of a higher cognitive order. So too are learning methods that use of concepts and principles to solve problems, those that encourage the use of one's own ideas, and those that relate physics to real life. This combination of numbers, concepts and principles as the preferred method of learning represents a shift from the traditional science curriculum approach to solving problems. The result is not an outlier; it is consistent with other results. For example, the second most popular method of learning was the use of concepts and principles. Hence, it is apparent that this cohort of students was more suited to the conceptual approach to solving problems.

Despite the higher cognitive order of the learning methods of the students, the influences of the traditional science curriculum and its approach to teaching is still evident. A fair proportion of students listed using memorization and numbers only, as learning methods. The figures for these teaching methods are almost equivalent to those who listed relating physics to real life and the use of one's own ideas to understand physics. Hence, one can conclude that although the learning methods experienced most frequently by the students are not a mirror image of the teaching methods, the influence of traditional teaching practices cannot be ignored when examining the learning methods of the students.

The comparisons between the learning and teaching methods were based on frequency counts and graphical representations. It would be interesting to discover through statistical analysis whether relationships do in fact exist between the teaching and learning methods experienced by the students. This analysis follows below.

4.3.3. Relationships that exist between the different 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 was used. The test compared for example, whether a chalk and talk approach to teaching corresponds with a "memorizing of notes" learning experience, i.e. is there any dependence between the two variables.

The null hypothesis for this chi-square test was that there was no dependence between the kinds of teaching and learning experiences of the students. However, if the probability value yielded was less than 0.05 then there was dependence between the teaching and learning experiences at a 5 percent level. Additionally, if the probability value yielded was less than 0.1 and greater than 0.05 then there was dependence between the teaching and learning experiences on a 10 percent level. The phi coefficient was a measure of the strength of the dependence in a table. The closer the phi coefficient was to 1 or –1, the stronger the relationship. The usefulness of the phi-coefficient in the comparison of probability values across tables is summarized in Table 4.2. The phi coefficient is inversely proportional to the Chi-Squared probability value, i.e. as the probability value increases, the phi-coefficient decreases proportionately.

The first challenge encountered at this level of analysis between the teaching and learning methods related to the combination of the groups. As mentioned above, the frequency of the teaching and learning methods was categorized using the following frequency descriptors: always; most times; a few times; and never. In order to establish whether dependence existed between a set of teaching and learning experiences, the chi square test statistic compared the frequency descriptors of the particular teaching and learning experience. However, the tests were not valid when the frequency descriptor groups were compared in their original state. The only alternative then was to combine the groups and then apply the chi-square test statistic. The frequency descriptors were combined as follows: (1) Always and Most Times were combined into the category titled Often; and (2) A Few Times and Never were combined into the category titled Seldom. Table 4.2 shows the level of dependence between teaching and learning methods.

Teaching Methods	Learning Methods	P< 0.1	P<0.05	Phi-Co efficient
Science Experiments (V98)	Relate Physics to Real Life (V108)		0.0012	0.2499
Work in Small Groups (V99)	Solve problems using Numbers, Concepts and principles (106)		0.0042	0.2236
Science Experiments (V98)	Use own ideas to understand new information (V107)		0.0091	0.2012
Problem Solving (V97)	Solve problems using Numbers, Concepts and principles (106)		0.0158	0.1867
Science Experiments (V98)	Solve problems using Numbers, Concepts and principles (106)		0.0439	0.1559
Textbooks (V95)	Solve problems using Numbers, Concepts and principles (106)	0.0598		0.1457
Textbooks (V95)	Memorization (102)	0.0607		0.1452
Questions and Answers (V96)	Use own ideas to understand new information (V107)	0.0613		0.1444
Work in Small Groups (V99)	Use own ideas to understand new information (V107)	0.0628		0.1449
Questions and Answers (V96)	Solve problems using Numbers, Concepts and principles (106)	0.0693		0.1406
Questions and Answers (V96)	Relate Physics to Real Life (V108)	0.0906		0.1309
Questions and Answers (V96)	Solve problems using Numbers only (V103)	0.1025		0.1267
Questions and Answers (V96)	Solve problems using Concepts and principles (104)	0.1025		0.1267
Questions and Answers (V96)	Memorization (102)	0.1071		0.1247

Table 4.2. The Dependence of Teaching and Learning Methods using the Chi-square Test Statistic – Ranked Distribution

As mentioned above, the null hypothesis for this test was that there was no significant relationship between the kinds of teaching and learning experiences of the students. However, according to Table 4.2. several relationships do exist between the teaching and learning experiences of the students. Some of the relationships exist at a 5 percent probability level, and some of them exist at a 10 percent probability level. The phi-coefficients are correspondingly further away from 1 as the dependency of the relationship decreases (note that as the p scores increase as one proceeds down Table 4.2. there is a corresponding decrease in the phi-coefficients). Moreover, the phi-coefficients are also further from 1 as one proceeds down Table 4.2. suggesting a decreasing level of dependence between the teaching and learning strategies for low phi-coefficients.

The strongest dependence between teaching and learning experiences of the students exists where the probability values are less than 0.05. According to Table 4.2. the strongest dependence at the 5 percent level, is for Science Experiments as a teaching method and Relating Physics to Real Life as a learning method with a probability value of 0.0012 and a corresponding phi-coefficient of 0.2499. This phi-coefficient is the closest value to 1 in all of Table 4.2.

Amongst the relationships that exist at the 5 percent probability level, the most popular teaching method was Science experiments and the most popular learning method was the use of numbers, concepts and principles to solve problems. Other teaching methods at the 5 percent probability level included Problem Solving and Working in Small Groups. The third and remaining learning method at the 5 percent probability level pertains to the use of one's own ideas to understand new information.

It is most interesting to note that the dependence at the 5 percent probability level exists between the teaching and learning methods that conform more to outcomes-based education than they do to the traditional science curriculum. Indeed, teaching methods like the use of experiments, problem solving, and working in small groups, is more consistent with the outcomes-based philosophy as outlined above. The corresponding learning methods of relating Physics to real life, using one's own ideas to understand new information, and the use of numbers, concepts and principles to solve problems confirms existence of an outcomes-based education framework in the teaching and learning methods that are most dependent on each other.

Amongst the other relationships that exist between teaching and learning experiences of the students, particularly those with probability values of less than or approximately 0.1, the nature of the traditional curriculum becomes very evident. The traditional science curriculum manifests itself in the teaching method of Questions and Answers featuring as the most frequent type of teaching for which there were corresponding learning methods of dependence. Nonetheless, it is apparent that the students used a combination of learning methods in response to this particular teaching method of Questions and Answers. The corresponding students responses ranged from the traditional (as in memorization and using numbers exclusively in solving problems) to the outcomes-based approach (as in relating Physics to real life situations, and using their own ideas to understand new information).

Another test statistic was administered to establish whether any relationships existed between the kinds of teaching and learning experienced by the students. The test statistic was the Pearson correlation coefficient, which is depicted mathematically as r. The value of r ranges from -1 to $+1$ and the relationship between the two variables is more significant if the value of r is closer to zero. Of all the teaching and learning methods experienced by the students, there were relationships of varying significance between some of the teaching and learning experiences. The Pearson correlation coefficient test results were similar to that of the Chi-square test discussed above. The smallest r-value of less than 0.0001 were for the teaching methods of using Science Experiments and Working in Small Groups. Both of these teaching methods were closely related to the learning method of using numbers, concepts and principles. Note that at the 5 percent probability level in Table 4.1. Science Experiments was the most popular teaching method and the use of numbers, concepts and principles was the most popular learning method.

4.4. Conclusion

This chapter set out to provide a response to the first critical question of this thesis, i.e. what was tbe 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? Most of the findings related to the first critical question can be separated into those which are informed by empirical data (derived from the questionnaire administered to the students – see Appendix 1). These findings are labelled as essential findings. The other findings, wbich have a theoretical underpinning, and are derived from the comparison of the traditional and transformational OBE curricula, will be classified as supplementary findings.

The first essential finding confirmed that the teaching methods of students who experienced traditional science curricula at school were largely conventional. Chalk and talk was the most frequent kind of teaching experienced by the students. The second most frequent teaching method entailed the use of questions and answers. Both of the most popular teaching methods are consistent with the supplementary theoretical finding that the learning theory of Behaviourism had a significant influence on the teaching practices of educators. There are striking differences between traditional teaching methods and those proposed within the transformational OBE framework. OBE in South Africa signals a change "from a talk and chalk – rote learning system to being flexible and (adapting) to learner needs and different learning styles and learning preferences" (DOE 1997b:42).

The second essential finding established that science experiments and group work, were the least popular of the teaching methods. There are two supplementary findings that inform this second essential finding. First, there were no deliberate attempts to fully integrate theory and practicals in the traditional curriculum. This artificial separation is in direct conflict with the transformational OBE approach, which encourages "the setting of tasks that integrate theory and practice, the manual and the mental learning where practicable, and which link the classroom learning to the broader society in which it is located" (DOE 1996a:46).

The other supplementary finding which supports this second essential finding was that, for the most part, the traditional curriculum ignored the fact that students are sources of subject knowledge, skills and attitudes. Textbooks prescribed in a recipe format the 'experimental method,' and provided the answers to the so-called discovery questions immediately after the experiment. On the other hand, transformational OBE explicitly endorses group work and appreciates the students as sources of knowledge, skills and values. More specifically, transformational OBE endorses the learning theory of Constructivism in which learners construct new knowledge using their original ideas.

The third essential finding established that the learning experiences of the students were not consistent with teaching methods. The most common learning method amongst the students was the use of numbers, concepts, and principles to solve problems. Supplementary findings indicate that this learning method is more consistent with the transformational OBE curriculum. In fact, this essential finding resonates with one of the specific outcomes for the Natural Sciences as outlined in the Discussion Document of C2005, namely: "Demonstrate an understanding of concepts and principles, and acquired knowledge in the Natural Sciences" (DOE 1997a:134). The use of higher order learning methods could also be attributed to the fact that the teaching methods that were experienced by the students were not exclusively traditional. For example, problem solving was the third most popular kind of teaching experienced by the students.

The fourth essential finding confirms that despite the tendency of the students to favour conceptual approaches to problem solving, traditional learning methods like memorization and the use of numbers exclusively to solve problems were still very popular. The supplementary finding pertaining to the significant effect of Behaviourism on the traditional curriculum applies to this essential finding. Additionally, the underlying educational philosophies of Essentialism and Perennialism also impacted the learning methods embraced by the students as they underpinned the traditional curriculum. Another supplementary finding pointed to the assessment system of the traditional curriculum encouraging traditional learning methods like memorization and the use of numbers exclusively to solve problems. The traditional assessment system was designed to test mastery of knowledge. This meant that huge volumes of information had to be retained by students to be restated in the examinations. In contrast to the traditional curriculum, the shift to OBE requires a formative and summative approach to assessment, as teachers must assess learners' progress continually. Assessment in an OBE system enables both learners and teachers to determine whether learners are achieving the agreed outcomes or not.

Fifth and finally, the chi-square test statistic and the Pearson Correlation Coefficient confirm that there is dependence at a five and ten percent level between some of the teaching and learning experiences of the students. The strongest dependence at the five-percent level using the chi-square test statistic is between the science experiments teaching method and relating physics to real life as a learning method. There are implications of this finding for the implementation of the transformational OBE. You have to tailor the course offerings so that the teaching method develops the desired learning method. For example, if you wanted students to use numbers, concepts and principles to solve problems, then Table 4.2. states that you should engage Science Experiments and Group work as teaching methodologies. Similarly, for those dependencies that exist at the five and ten percent level, corresponding teaching methods should be applied to achieve a desired learning strategy in students.

Chapter Five

An Analysis of Scientific Literacy Levels of Traditional Science Curriculum Students

5.1. Orientation to the Chapter

This chapter will examine critical question two, i.e. what were the levels of scientific literacy in the selected cohort of undergraduate science students? As mentioned in chapter one, the second critical question is included to determine the effects of the traditional science curriculum on scientific literacy levels of the students. This critical question presents science in real life situations and will therefore expose the extent to which students use the information learned at school in their everyday lives. Moreover, this question embraces innovative, C2005 aligned approaches to measure scientific literacy levels. This alignment to C2005 represents a new dimension in the measurement of scientific literacy levels. The principal focus of this chapter is on the analysis of the results of the scientific literacy test completed by the selected students. This analysis is preceded by two precursor components. First, a preview to the data analysis component to highlight factors that will inform the analysis of scientific literacy scores. Second, a tests and plots component to establish whether the scientific literacy scores of the selected students are normally distributed.

5.2. Preview to Data Analysis

This component of the chapter orients the reader to the analysis of scientific literacy data by briefly addressing two foundational issues. First, a discussion on the nature of the scientific literacy questions. Second, the rationale for testing the scientific literacy data for normality, and subsequent tests and frequency plots to test for normality of the data.

The source of data pertaining to the scientific literacy levels of the students, as mentioned in chapter three (see sub-section 3.4.1.2. pp.49-53), were twenty multiple-choice questions that were linked to four science themes (Earth & Beyond, Matter & Materials, Life and Living, and Energy and Change) from the Natural Science learning area of C2005. The twenty questions were part of the all-inclusive questionnaire that was administered to the students. The twenty questions were not confined to conceptual knowledge exclusively as they included a distinct element of extrapolation and application of the science concepts to real life situations. Thus, the questions lent themselves largely to the "comprehension and application levels" in Bloom's taxonomy of educational objectives: cognitive domain, (Ornstein & Hunkins 1998:280). Comprehension and application are the second and third levels in Bloom's hierarchy of educational objectives: cognitive domain. There were also questions that were more suited to Bloom's first level of educational objectives, namely: knowledge. Bloom's fourth, fifth and sixth levels of educational objectives (analysis, synthesis, and evaluation respectively) did not feature in the classification of the twenty questions on scientific literacy. It must be emphasized that 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 variables, themes, concepts, and Bloom's levels of educational objectives: cognitive domain, which were linked to the twenty questions on scientific literacy, are listed in Table 5.1. below:

Variable	Theme	Concept/s	Bloom's Taxonomy Level
2	Earth & Beyond	Greenhouse effect	Knowledge
3	Earth & Beyond	Acid Rain	Comprehension
4	Earth & Beyond	Ozone depletion	Knowledge
5	Earth & Beyond	Seasons	Comprehension
6	Earth & Beyond	Force of Gravity	Application
7	Matter & Materials	Density	Application
8	Matter & Materials	Inertia	Application/Knowledge
9	Matter & Materials	Action- Reaction	Application/Comprehension
10	Matter & Materials	Momentum	Application/ Comprehension
11	Matter & Materials	Boiling Point	Comprehension
12	Life and Living	Cellular respiration	Knowledge
13	Life and Living	DNA	Comprehension
14	Life and Living	pH	Comprehension
15	Life and Living	Enzymes	Comprehension
16	Life and Living	HIV/AIDS	Comprehension
17	Energy and Change	Electricity	Knowledge
18	Energy and Change	Energy Changes	Application
19	Energy and Change	Conduction	Knowledge
20	Energy and Change	Colour	Comprehension
21	Energy and Change	Friction	Application

Table 5.1. The Classification of Scientific Literacy Questions according to theme, concepts, and Bloom's levels of educational objectives: cognitive domain

Now that the nature of the questions on scientific literacy has been visited, the second foundational issue of this sub-section can be explored, namely normality of the scientific literacy data. As mentioned above, the testing of the scientific literacy data for normality was necessary as the variable on the scientific literacy represented a dependent variable in this study. Scientific literacy was dependent on a variety of factors including the first language of a student. This dependent variable was first tested for normality to determine whether parametric or non-parametric statistical tests can be used when analyzing the related data. Parametric tests are based on the distributional assumption of normality, while non- parametric tests are based on the distributional assumption of abnormality.

The nature of the tests and frequency plots conducted included the Shapiro-Wilk statistical test, and stem-and-leaf plots, box plots, and probability plots. The Shapiro-Wilk statistical test was administered to establish whether the data related to scientific literacy were normally distributed. Thereafter, stem-and-leaf plots, box plots, and probability plots were completed to illustrate the distribution of the scientific literacy data (see Figure 5.1. p.116). These plots are presented alongside one another below for each data set to illustrate the distribution of the same data in three different ways. The results of the Shapiro-Wilk statistical test and frequency plots are discussed below.

5.3. Tests and Plots for Normality of Scientific Literacy Scores

The Shapiro-Wilk test statistic value of 0.978239 ($p = 0.0087$) was obtained which is significant at a five percent level. Therefore, the null hypothesis of normality was rejected, and the data is not normally distributed. However, the stem-and-leaf plot, the box plot and the normal probability plot reveal that the deviation from normality is not great. The near normal distribution of scientific literacy test scores of the students is displayed more prominently in each of the frequency plot illustrations that follow:

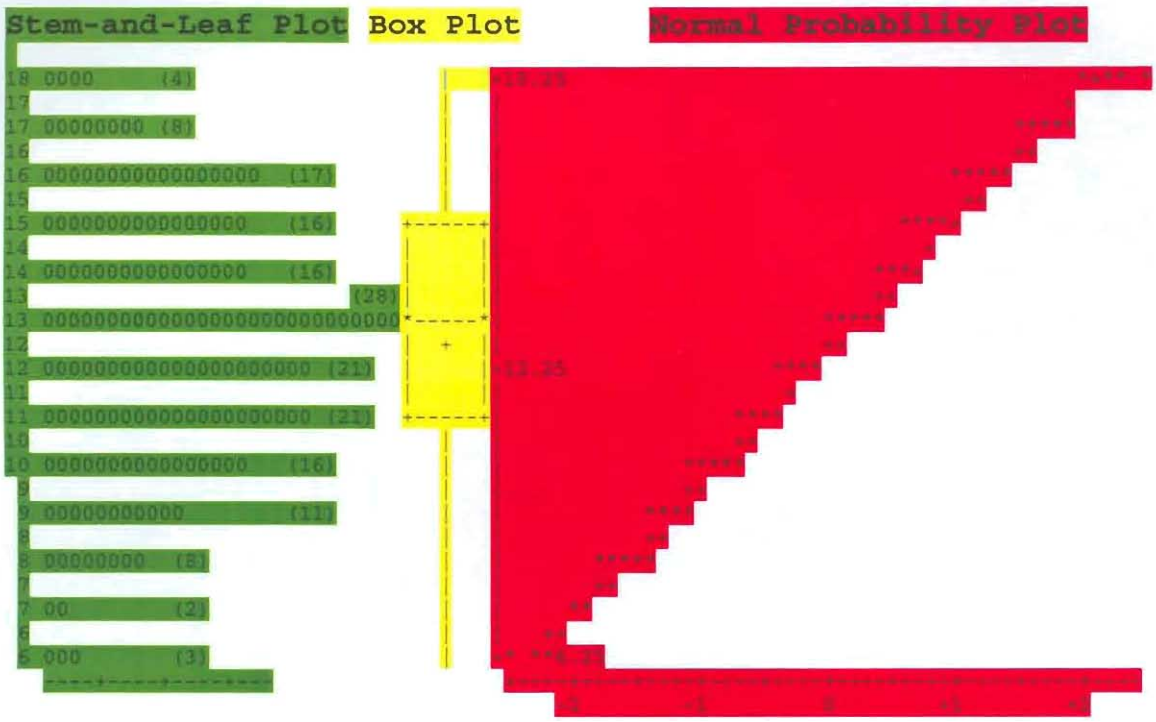

Figure 5.1. Frequency Plots of Scientific Literacy Scores

The stem-and leaf plot corresponds closely with a bell shaped distribution of the data on scientific literacy scores, hence a near normal distribution can be assumed. The mode and the peak are at a score of 13, with a frequency of 28. The bell shape extends over a range of scores from 16 through to 10, and the base of the bell becomes asymptotic with the limited number of low frequency scores of 17 to 18 on one side, and 6 to 9 on the other side.

The Box plot confirms the near normal distribution of the data on scientific literacy scores with a clustering of scores between 11 and 15 and a symmetrical distribution on either side. The median of the box plot is indicated by the central horizontal line, and the central + sign indicates the mean. The box plot is slightly negatively skewed because the mean is less than the median. The near normal distribution is expressed by the closeness of the median and mean in the box plot.

The Normal Probability plot yielded almost a straight line indicating a near normal distribution of the data on scientific literacy levels of the students.

Thus, the three frequency plots are in sync and the deviation from normality of the scientific literacy scores can be considered minimal.

Further analysis of the frequency plots yielded the following observations:

LOWEST SCORE		HIGHEST SCORE		MEAN	MEDIAN	MODE
Value	Frequency	Value	Frequency			
6	3	18	4	12	13	13

Table 5.2. Statistical Overview of Scientific Literacy Levels of the Students

According to Table 5.2, the lowest score was 6 with three students achieving this score, and the highest score was 18 with four students achieving this score. As mentioned above, the mean and median differ slightly and this is illustrated in Table 5.2. with a differential of just one between the mean and median of 12 and 13 respectively.

The above tests for normality, frequency plots and analysis of extreme observations related to the data on scientific literacy levels of the students all helped to provide an understanding of the parameters and patterns of the scientific literacy levels of the students. It also helped to contribute to an objective assessment and acceptance of the normal distribution of the scientific literacy data. Thus, parametric statistical tests can be used to analyze the data on scientific literacy.

Now that both the nature of the questions and the distribution of the data have been discussed, the focus of this chapter will now shift to the analysis of scientific literacy levels.

5.4. <u>Analysis of Scientific Literacy Levels of the Selected Cohort of Science Students</u>

This component of the chapter will address critical question two, namely, what were the levels of scientific literacy in the selected cohort of undergraduate science students?

To determine the levels of scientific literacy of the students, the following method was employed:

The variables V2 through to V21 related to the test for scientific literacy, i.e. questions that related to the conceptual knowledge of science as well the application of that knowledge in life were provided to students (see sub-section 3.4.1.2. pp.49-53, and Appendix 1).

The correct responses to these questions are listed in Table 5.3. below:

Variable	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Correct Response	4	2	4	3	4	3	4	1	1	4	3	3	4	4	4	4	3	2	2	2

Table 5.3. Correct Responses to Scientific Literacy Questions

It was originally intended to classify students as follows:

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

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 5.4. The General Distribution of Students' Scores for Scientific Literacy

It can be discerned from Table 5.4. that most of the scores for scientific literacy were clustered between 9 and 16 with some of the scores being distributed on the extremes. Thus, the majority (approximately 75,4 %) of the students were of mediocre or good scientific literacy, and a limited number (7,6 %) of students were scientifically illiterate, and a reasonable number (17 %) of the students had an excellent scientific literacy.

The detailed distribution of scientific literacy scores reveals a range from 6 through to 18. Table 5.5. below illustrates the detailed distribution of students' scores for scientific literacy. The acronym TOTS is used to abbreviate the total score for scientific literacy. The FREQ Procedure data were used to generate Table 5.5.

Scientific Literacy or TOTS	Frequency	Percent
6	3	1.8
7	2	1.2
8	8	4.7
9	11	6.4
10	16	9.4
11	21	12.3
12	21	12.3
13	28	16.4
14	16	9.4
15	16	9.4
16	17	9.9
17	8	4.7
18	4	2.3

Table 5.5. The Detailed Distribution of Students' Scores for Scientific Literacy

The original categorization of students according to their levels of scientific literacy intended to classify students with scores of less than 8 into a scientifically illiterate category. However, from Table 5.5, it is obvious that this would have meant that only 5 students would feature in this category, i.e. those with scientific literacy scores of 6 and 7 out of 20. Therefore, as mentioned in section 5.4, when the Centroid method of cluster analysis was applied, the boundaries of this scientifically illiterate category were redefined to include a score of 8, thereby making the data more statistically viable. Hence, the category of scientifically illiterate was comprised of 13 students.

Table 5.5. also reveals that there were no absolute scores for scientific literacy, i.e. none of the students achieved a score of 20 out of 20. Also, none of the students scored 0 to 5 which means that those in the scientifically illiterate range (0 to 8 out of 20) were clustered on upper end of the scientifically illiterate continuum. Additionally, Table 5.5. shows that the most frequent score for scientific literacy was 13 out of 20 with 28 students or 16,4 % recording that score. This finding was also discussed in the Stem-and-Leaf frequency plot analysis of scientific literacy data above (see sub-section 5.3. pp.115-117).

These detailed scientific literacy scores are accentuated in the Figure 5.2. below.

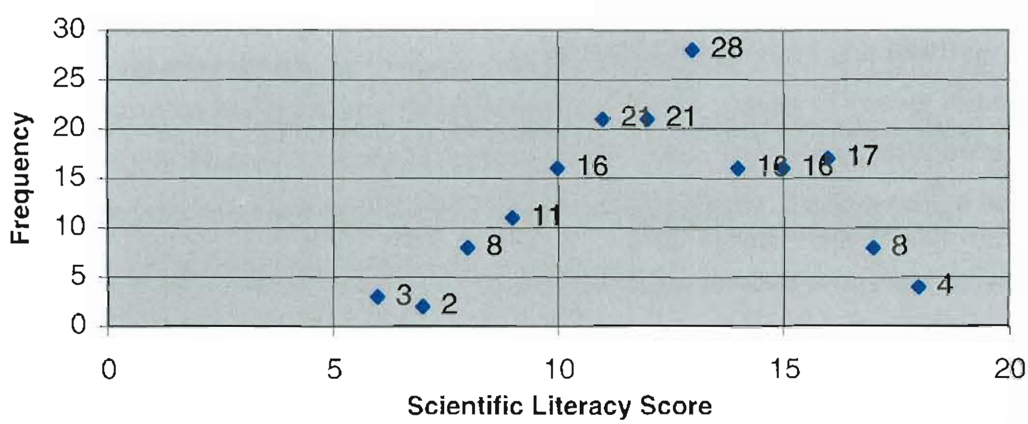

Figure 5.2. The detailed distribution of Scientific Literacy Scores

The above scores for scientific literacy were then examined to determine which questions were answered correctly in each of the categories of scientifically literate students. Such an analysis revealed patterns with regard to the nature of questions correctly answered by each of the groups. This is a new dimension in the analysis of the scientific literacy levels of the students. The analysis entails an examination of the questions with the most, moderate and least number of correct responses by concept, theme, discipline, and an explanation of the patterns that emerge. The analysis of the scores for scientific literacy of each group of students (Scientifically Illiterate, Mediocre Scientific Literacy, Good Scientific Literacy, Excellent Scientific Literacy) is presented below.

5.4.1. Analysis of Scientific Literacy Scores of Scientifically Illiterate Students

The first group of students analyzed were the ones with total scores of less than or equal to 8 out of 20 for the test on scientific literacy. They were thus classified as scientifically illiterate, and the total number of students that were in this category was 13. Figure 5.7. below depicts the frequency of correct responses against the variables linked to the questions on scientific literacy.

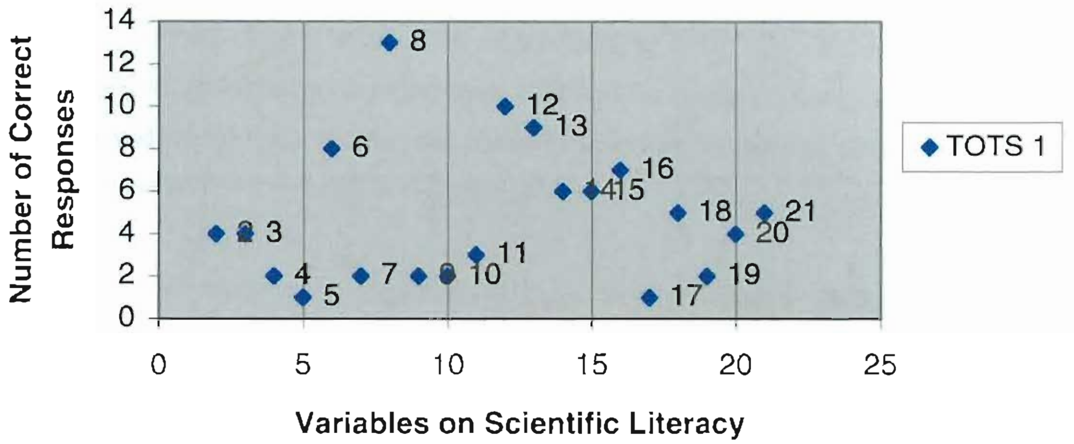

Figure 5.3. Distribution of Correct Responses by Scientifically Illiterate (TOTS 1) Students

According to Figure 5.3. the scientifically illiterate students provided the most number of correct responses for variables 8 (100 %), 12 (77 %) and 13 (69 %). Variable 8 related to inertia, variable 12 to cellular respiration, and variable 13 to genetics. Upon closer examination of variables 8, 12 and 13, it is apparent that there is a bias amongst the scientifically illiterate students towards the Life Sciences. This bias is attributed to two (12 and 13) of these three variables being directly related to the theme of Life and Living, which is central to the discipline of the Life Sciences. Also, the question with the most number of correct responses, the inertia question, was relatively simple, and this could have been the cause of a disproportionately higher number of correct responses to this question. Variable 8 has a dual status of application/knowledge (Bloom's taxonomic levels) in Table 5.1. which relegates it to a low cognitive level question. It is simply the restatement of Newton's first law of motion and is a daily experience.

The moderately scored variables (6, 14, 15, and 16) reflect a balance between the Life and Physical sciences as popular disciplines for the scientifically illiterate group. Variables 6 (acceleration due to gravity), 14 (pH), 15 (enzymatic action), and 16 (AIDS) represent a combination of the Life and Physical Sciences.

As for the Earth Sciences, the performance of these students was unsatisfactory because the associated variables 2, 3, 4, and 5 were scored poorly. The Earth Science variables concerned global warming, weathering, ultra violet rays and seasonal change respectively. The performance of the scientifically illiterate students on Earth Science variables 2, 3, 4, and 5 were scored as follows: 4 out of 13 (31 %), 4 out of 13 (31 %), 2 out of 13 (15 %) and 1 out of 13 (8 %) respectively. The average score for the Earth Sciences questions was therefore 21 %.

Variables 5 and 17 had the least number of correct responses for the scientifically illiterate students. There was just one correct response each for variables 5 and 17. Variable 5 related to seasonal change and variable 17 related to the kilowatt-hour (kWh), the unit in which electricity is bought. The question on seasonal change is a concept integral to the theme Earth and Beyond, and was one of the most difficult questions that featured in the test on scientific literacy. The difficulty in the seasonal change question lay in it being a comprehension (Bloom's taxonomy) type question but with an extrapolation of knowledge about planets at an abstract level. The question that related to the kWh required some knowledge of how units can be manipulated, as it is a disguised form of the unit joule, which is the conventional Systems Internationale (SI) unit for energy. However, on electricity bills energy is measured in kWh not joules, and to apply scientific knowledge responsibly requires an understanding of the different forms that the same information can take in different contexts.

Overall, the students who were classified as scientifically illiterate displayed the following tendencies: the questions with the most frequent number of correct answers suggests a popularity of the Life Sciences; those with a moderately number of correct answers reflects a balance between the Life and Physical Sciences; and the questions with the least number of correct answer pertained to the Earth and Physical Sciences. Additionally, the Earth Science questions were poorly answered. Therefore, one can infer that the order of popularity of disciplines for the scientifically illiterate students decreases in the following sequence: Life Sciences, Physical Sciences, and Earth Sciences.

The same pattern of analysis as above will follow for each of the remaining three groups of students with different scientific literacy levels to establish any similarities and differences in the kinds of questions answered most frequently by each of the groups of students.

5.4.2. Analysis of Scientific Literacy Scores of Students with Mediocre Scientific Literacy

The second group of students analyzed were those with total scores of 9 to 11 out of 20 for the test on scientific literacy. They were thus classified as being students with a mediocre scientific literacy, and the total number of students that were in this category was 48. Figure 5.4. below depicts the frequency of correct responses against the variables linked to the questions on scientific literacy for students of mediocre scientific literacy.

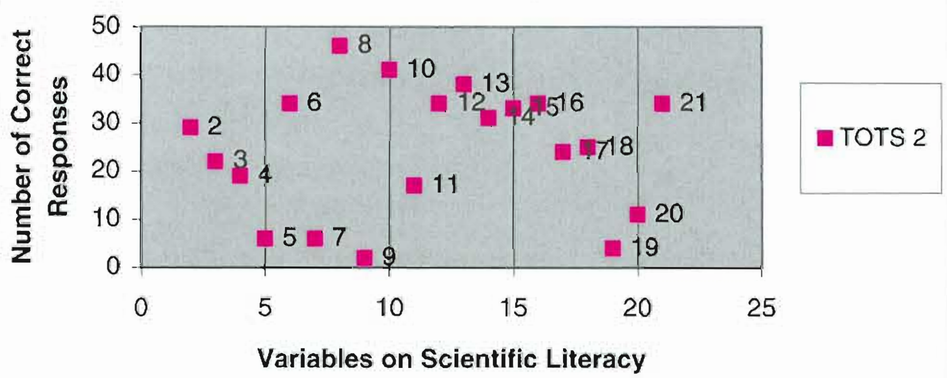

Figure 5.4. Distribution of Correct Responses by Students with a Mediocre Scientific Literacy (TOTS 2)

As was the case with the scientifically illiterate students, variable 8 had the most number of correct responses. A total of 46 (96 %) of students with a mediocre scientific literacy selected the correct response to this question. As mentioned above this question related to inertia, the tendency of a body to resist changes in its state of motion, and was the easiest of all the questions thus giving it a disproportionately high scoring. Considering that variable 8 on inertia was a relatively simple question, it can be ignored when determining the most popular disciplines of the students with a mediocre scientific literacy.

Other variables with a large number of correct responses include variable 10 (85 %) and 13 (79 %). Variable 10 related to the concept momentum, which is part of the theme Energy and Change, a core component of the Physical Science syllabus in Grade 12. The high frequency of correct responses to the relatively difficult variable 10 is a manifestation of the higher order thinking skills of this group compared to the scientifically illiterate students who scored only 2 correct responses (15 %) for this same question. Variable 10 is classified as an application/comprehension question (Bloom's taxonomic levels) in Table 5.1.

Variable 13 related to genetics and was also popular amongst the students with mediocre scientific literacy as it was with the students who were scientifically illiterate. Genetics is a core topic in the Life Sciences syllabus. Therefore, it can be inferred from these two variables (10 and 13) with the most number of correct responses that the students with a mediocre scientific literacy have an affinity for both the Life and Physical Sciences.

Upon closer examination of Figure 5.4. the clustering of a moderately high number of correct responses to variables 6 (acceleration due to gravity), 12 (cellular respiration), 14 (pH), 15 (enzymatic activity), 16 (HIV/AIDS), and 21 (frictional force), confirms a balance between the Life and Physical Sciences for students with mediocre scientific literacy. Acceleration due to gravity and frictional force are clearly Physical Science concepts, cellular respiration and HIV/AIDS are within the Life Sciences realm and the remaining two concepts are cross cutting.

According to Figure 5.4. the least popular questions for this group of students with a mediocre scientific literacy were linked to variables 9 (vector sum of forces) and 19 (conduction). Variable 9 was indeed a very challenging question as students had to compare the two options of pushing and pulling an object with vector diagrams and then determine whether pushing or pulling is easier by comparing the resultant force exerted by the ground on the object being pulled. Variable 19 was also a tricky question, as it is commonly known that Copper is used as a conductor in most electrical connections. However, the General Science curriculum at schools emphasizes that the conduction properties of Silver are superior to that of Copper. The only reason why Copper is used more extensively is because it is relatively inexpensive compared to using Silver. Thus, the two questions which students of mediocre scientific literacy found most challenging related to the Physical Sciences. This finding related to the least popular questions therefore reduces the popularity of the Physical Sciences amongst students of mediocre scientific literacy. Overall, the Life Sciences has emerged as the most popular discipline amongst these students of mediocre scientific literacy.

Additionally, the Earth Sciences were not as popular as the Life Sciences (see Figure 5.4. p.123). The performance of the students on the questions related to the Earth Sciences (variables 2, 3, 4 and 5) was not as impressive as the questions on the Life Sciences. The Earth Science questions concerned global warming, weathering, ultra violet rays and seasonal change. The actual number of correct responses for students with mediocre scientific literacy on variables 2, 3, 4 and 5 were 29 (60 %), 22 (46 %), 19 (40 %) and 6 (13 %) respectively out of a possible maximum of 48. The average score for the Earth Science questions was therefore 40 %.

The trend thus far is a bias towards questions on the Life Sciences. It would be interesting to see how this trend changes as the levels of literacy improve. These changes are discussed below with the examination of the last two groups of students, namely those with good and excellent scientific literacy.

5.4.3. <u>Analysis of Scientific Literacy Scores of Students with Good Scientific Literacy</u>

The third group of students analyzed were those with total scores of 12 to 15 out of 20 for the test on scientific literacy. They were thus classified as being students with a good scientific literacy, and the total number of students that were in this category was 81. Figure 5.5. below depicts the frequency of correct responses against the variables linked to the questions on scientific literacy for students of good scientific literacy.

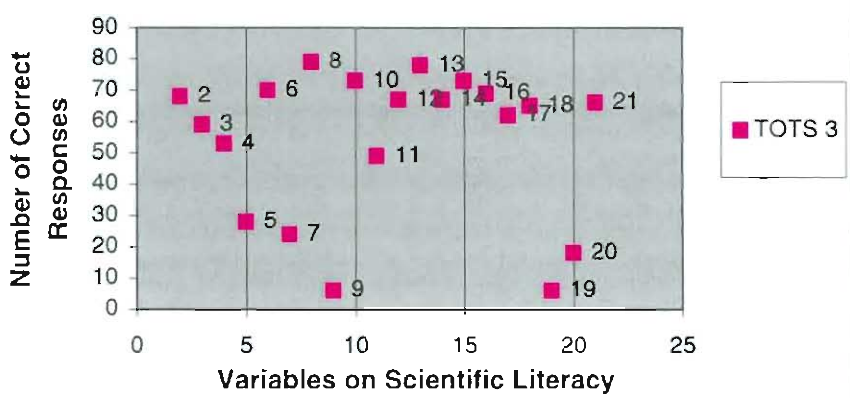

Figure 5.5. Distribution of Correct Responses by Students with Good Scientific Literacy

Once again, the most number of correct responses went to variable number 8 that related to the concept inertia. According to Figure 5.5, the total number of correct responses for variable 8 was 79 (98 %) out of a total of 81 students in the category good scientific literacy. As mentioned above, the high frequency of correct responses for variable 8 can be attributed to this being the simplest of questions as it was simply a restatement of Newton's first law of motion.

There are several glaring differences between the distribution of correct responses by these students with a good scientific literacy compared with those who were scientifically illiterate or those with a mediocre scientific literacy. For example, the performance of these students on the Earth Sciences questions is considerably better than that of the former two groups. According to Figure 5.5, the number of correct responses to the Earth Science variables 2, 3, 4, and 5 were 68 (84 %), 59 (73 %), 53 (65 %), and 28 (35 %) out of a maximum score of 81. Thus, the average score for the Earth Science questions for the students with good scientific literacy was 64 %. This figure is considerably higher than the average scores for the scientifically illiterate students and those with mediocre scientific literacy who scored 21 % and 40 % averages respectively. Furthermore, the population size of the students with a good scientific literacy is far greater than those in the first two groups of students. Sometimes percentages can be misleading; however, in this case the performance of students is better both in percentage and actual number.

Another glaring difference of these students with a good scientific literacy is a distinct separation of the high scoring variables from the low scoring variables as illustrated in Figure 5.5. In the distribution of correct responses for the scientifically illiterate and those with mediocre scientific literacy, there is a circular scattering of the high and low scores. This distinct separation of scores for students with a good scientific literacy is reflective of the majority of the students in this group having the same abilities and understanding of scientific phenomena.

The lowest scoring variables for students with a good scientific literacy were 9 (vector sum of forces) and 19 (conduction). Interestingly, these questions were also the lowest scoring ones for students with a mediocre scientific literacy.

With regard to the type of questions that were most popular amongst these students with a good scientific literacy, one could assume, based on an analysis of Figure 5.5. that there is no preference as there is almost a similar kind of scoring for Earth Sciences, Physical Sciences and Life Sciences. This equivalence is suggested by the almost linear distribution of high scores across a combination of disciplines. However, with the low scoring variables 5 (seasonal change), 7 (density), 9 (vector sum of forces), 19 (conduction) and 20 (colour of light), there an overall weakness related to the Physical Sciences. Variables 7, 9, 19, and 20 were part of the Physical sciences, and the variable 7 part of the Earth Sciences. Therefore, one can conclude that the students with a good scientific literacy were more favourably disposed to questions on the Life and the Earth Sciences. Interestingly, there is a distinct shift from the first two groups (scientifically illiterate and those with mediocre scientific literacy) who were more favourably disposed to the Life Sciences. This analysis creates an interesting backdrop for the analysis of scores for the students with excellent scientific literacy as it would be interesting to discover whether the preferred type of questions are similar or different and how the distribution of scores varies. The analysis of the scores for students with excellent scientific literacy follows.

5.4.4. <u>Analysis of Scientific Literacy Scores of Students with Excellent Scientific Literacy</u>

The fourth group of students analyzed were those with total scores of 17 to 20 out of 20 for the test on scientific literacy. They were thus classified as being students with excellent scientific literacy, and the total number of students that were in this category was 29. Figure 5.7. below depicts the frequency of correct responses against the variables linked to the questions on scientific literacy for students of good scientific literacy.

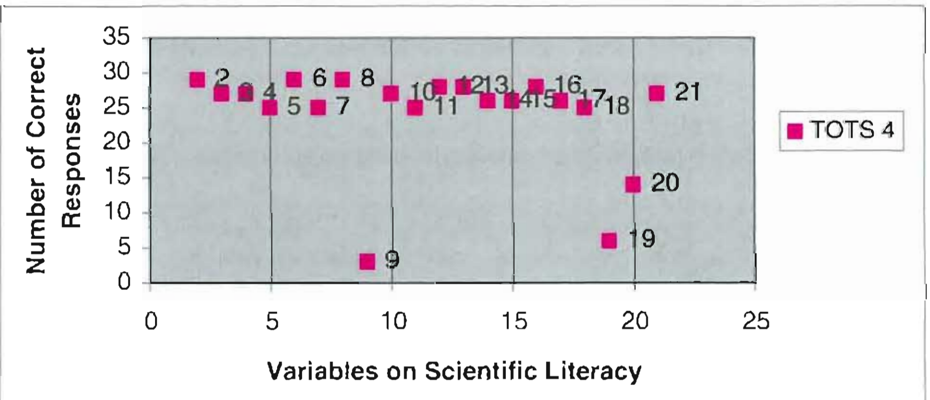

Figure 5.6. Distribution of Correct Responses by Students with Excellent Scientific Literacy

According to Figure 5.6, there is a greater consistency in the separation of high and low scoring variables for students with excellent scientific literacy as compared to those with a good scientific literacy. As mentioned above, the students with mediocre scientific literacy, as well as those considered scientifically illiterate, had a circular scattering of the high and low scores.

The consistency in the distribution of correct responses, as expressed in the almost linear distribution of scores in Figure 5.6. is suggestive of a uniform understanding of science concepts, and the application thereof, across the domain of science, i.e. these students have almost equal abilities and understandings in the Natural, Physical, and Earth Sciences. This equivalence in knowledge is manifested by equivalence in scores in Figure 5.6. above. Figures 5.3, 5.4, and 5.5 all had variable 8 as the one with the most number of correct responses. However, in Figure 5.6, variable 8 is not clearly distinguishable as the highest scoring variable. In the linear spread of variables with the most number of correct responses in Figure 5.6, variable 8 is just one of the highest scoring correct responses. In fact, variable 8 tied with variable 2 (greenhouse effect) and with variable 4 (acceleration due to gravity) as the variables with the most number of correct responses. All three of these top-scoring variables had absolute (100 %) scores of 29 out of 29. As the top scoring variables related to inertia, global warming and acceleration due to gravity, one could infer that there is a bias in these students with excellent scientific literacy for the Physical and Earth Sciences and not the Life Sciences. However, the closeness with which all the questions were scored correctly suggests equivalence in the abilities and understandings of these students across all three disciplines. The nearness in the scores is accentuated in the range of scores across the linear distribution of scores in Figure 5.6. i.e. there were 25 to 29 correct responses to most of the questions.

The lowest scoring variables for students with excellent scientific literacy were 9 (vector sum of forces) and 19 (conduction), with an average performance on variable 20 (colour of light). Coincidentally, variables 9 and 19 were the most poorly answered by the students with a good scientific literacy as well as the group of students with a mediocre scientific literacy. The students who were considered scientifically illiterate had the least number of correct responses to variables 5 (seasonal change) and 17 (kWh). As variables 9 and 19 are essentially Physical Science questions, one is inclined to believe that there is a weakness in this group of students in the Physical Sciences. However, their almost perfect scoring for other Physical Science questions, as expressed in the linear distribution of correct responses in Figure 5.6, eclipses their poor performance on these two questions. Thus, the core distillation from the above analysis of the students with excellent scientific literacy is that there is equivalence in the abilities and understandings of these students in all three disciplines, namely, the Physical, Life and Earth Sciences.

5.4.5. Summary of Most Popular Science Disciplines for Students with Different Scientific Literacy Levels

The preferences of the four groups of students are summarized in Table 5.6. below.

Scientific Literacy Level	Most Popular Discipline in Sciences
Scientifically Illiterate	Life Sciences
Mediocre Scientific Literacy	Life Sciences
Good Scientific Literacy	Life and Earth Sciences
Excellent Scientific Literacy	Life, Earth and Physical Sciences

Table 5.6. Most Popular Science Disciplines for Students with Different Scientific Literacy Levels

Table 5.6. is suggestive of an evolution of the students' abilities and understandings of science concepts and application thereof. Essentially, scientifically illiterate students and students with mediocre scientific literacy have a grasp of simple Life science concepts, students with good scientific literacy have evolved to a higher level with a good grasp of both the simple Life Sciences and the more challenging Earth Sciences, and students with excellent scientific literacy having reached the ultimate level with an equivalence in understandings across all three disciplines.

5.5. Conclusion

This chapter examined critical question two, i.e. what were the levels of scientific literacy in the selected cohort of undergraduate science students? The principal focus of this chapter was on the analysis of the results of the scientific literacy test completed by the selected students.

The lowest scientific literacy score was 6 with three students achieving this score, and the highest score was 18 with four students achieving this score. Most of the scores for scientific literacy were clustered between 9 and 16 with some of the scores being distributed on the extremes. Thus, the majority (approximately 75,4 %) of the students were of mediocre or good scientific literacy, and a limited number (7,6 %) of students were scientifically illiterate, and a reasonable number (17 %) of the students had an excellent scientific literacy.

The above scores for scientific literacy were then examined to determine which questions were answered correctly in each of the categories of scientifically literate students. Such an analysis revealed patterns with regard to the nature of questions correctly answered by each of the groups. This was a new dimension in the analysis of the scientific literacy levels of the students. The analysis entailed an examination of the questions with the most, moderate and least number of correct responses by concept, theme, discipline, and an explanation of the patterns, which emerged.

The core findings of this analysis of scientific literacy levels revealed that the order of popularity of disciplines for the scientifically illiterate students decreased in the following sequence: Life Sciences, Physical Sciences, and Earth Sciences. The Life Sciences also emerged as the most popular discipline amongst these students of mediocre scientific literacy. However, students with a good scientific literacy were more favourably disposed to questions on the Life and the Earth Sciences. Moreover, the students with excellent scientific literacy had equivalence in their abilities and understandings in all three disciplines, namely, the Physical, Life and Earth Sciences.

In the graphical distribution of correct responses for the scientifically illiterate and those with mediocre scientific literacy, there was a circular scattering of the high and low scores. This scattering of scores indicated that students in the scientifically illiterate and mediocre scientific literacy groups had different abilities and understandings across the three disciplines and within the same discipline as well. The distinct separation of high and low scores for students with a good scientific literacy reflected that the majority of the students in this group have the same abilities and understanding of scientific phenomena. There was a greater consistency in the separation of high and low scoring variables for students with excellent scientific literacy as compared to those with a good scientific literacy. Therefore, there was even greater uniformity in the abilities and understanding of scientific phenomena of students with excellent scientific literacy.

What is clearly discernible from the above analysis of scientific literacy levels of a cohort of students is that there will always be an assortment of abilities and understandings of scientific phenomena within any cohort of students. That assortment in abilities and understandings may be due to variations in teaching, to curriculum content, to student interests, or to a host of other reasons. In the above analysis, it is fairly obvious that the variety is due, in part, to preference or popularity of different disciplines in the Natural Sciences. This differentiation of students by discipline and level of scientific literacy could influence pedagogy and curriculum content in an attempt to improve the scientific abilities and understanding of the selected cohort of students.

Chapter Six

An Analysis of Technological Literacy Levels of Traditional Science Curriculum Students

6.1. Orientation to the Chapter

This chapter will examine critical question 3, i.e. what were the levels of technological literacy in the selected cohort of undergraduate science students? As mentioned in chapter one, the third critical question is included to determine the effects of the traditional science curriculum on technological literacy levels of the students. This critical question presents technology in real life situations and will therefore expose the extent to which students use the information learned at school in their everyday lives. Moreover, this question embraces innovative, C2005 aligned approaches to measure technological literacy levels. This alignment to C2005 represents a new dimension in the measurement of technological literacy levels. The principal focus of this chapter is on the qualitative analysis of the results of the technological literacy test completed by the selected students. This analysis is preceded by two largely quantitative precursor components. First, a preview to the data analysis component to highlight factors that will inform the analysis of technological literacy scores. Second, a tests and plots component to establish whether the technological literacy scores of the selected students are normally distributed.

6.2. Preview to Data Analysis

This component of the chapter orients the reader to the analysis of technological literacy data by briefly addressing two foundational issues. First, a brief review of the nature of the technological literacy questions, with a brief description of the differences between the analysis of technological literacy scores as compared to scientific literacy scores. 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 methodology that was embraced to test the technology literacy levels of the students was described in chapter three (see sub-section 3.4.1.2. pp.49-53 and sub-section 3.6.3. pp.71-72). Six open-ended questions, which corresponded to seven specific outcomes for technology, were developed and administered as part of the all inclusive questionnaire. Each of the six questions corresponded with a specific outcome for technology except for the last question that addressed both specific outcomes one and two. The classification of responses to each technology question was based on the SOLO Taxonomy (see sub-section 3.4.1.2. pp.49-53). Each response corresponded with a score from 1 to 5 as outlined below in Table 6.1.

SOLO Taxonomy Classification	Score
Prestructural	1
Unistructural	2
Multi-structural	3
Relational	4
Extended abstract	5

Table 6.1. The SOLO Taxonomy for Classification of Technology Scores

The variable on the technological literacy represented a dependent variable in this study because it is influenced by a variety of factors like academic performance in Grade 12 (matric). This dependent variable was first tested for normality to determine whether parametric or non-parametric statistical tests can be used when analyzing the related data. Parametric tests are based on the distributional assumption of normality, while non-parametric tests are based on the distributional assumption of abnormality.

The Shapiro-Wilk statistical test was administered to establish whether the data related to technological literacy were normally distributed. Thereafter, a stem-and-leaf plot, a box plot, and a normal probability plot were completed to illustrate the distribution of the technological literacy data (see Figure 6.1. above). These plots are presented alongside one another for each data set to illustrate the distribution of the same data in three different ways.

Before the results of the Shapiro-Wilk statistical test and frequency plots are discussed, a brief discussion of the differences between the analysis of technological literacy scores as compared to scientific literacy scores is presented.

First, the range of scores for scientific literacy was from 6 through to 18 out of a maximum of 20. The range of scores for technological literacy scores was from 1.18 through to 3.45 out of a maximum of 5. Second, the technological literacy scores were not whole or natural numbers as they represented the mean score for eleven sub-questions on technological literacy. (Note: Although there were six questions on technological literacy. Some of these questions consisted of multiple parts. Hence, there were eleven sub-questions on technological literacy.) The overview of technological literacy scores is presented in Table 6.2. below. Third, the corresponding mean, median and mode for technological literacy are lower, and not natural numbers as illustrated in Table 6.2. below.

LOWEST		HIGHEST		MEAN	MEDIAN	MODE
Value	Frequency	Value	Frequency			
1.18	7	3.45	2	2.13	2.09	2.18

Table 6.2. Statistical Overview of Technological Literacy Levels of the Students

The above overview of differences between the scientific and technological literacy scores paves the way for a discussion of the normality tests and frequency plots applied to the technological literacy data, which follows.

6.3. Tests and Plots for Normality of Technological Literacy Scores

The Shapiro-Wilk test statistic value of 0.984131 ($p = 0.0487$) was obtained which is significant at a five percent level. Therefore, the null hypothesis of normality was rejected, and the data is not normally distributed. However, the stem-and-leaf plot, the box plot and the normal probability plot reveal that the deviation from normality is not great. The near normal distribution of technological literacy test scores of the students is displayed more prominently in each of the frequency plot illustrations that follow:

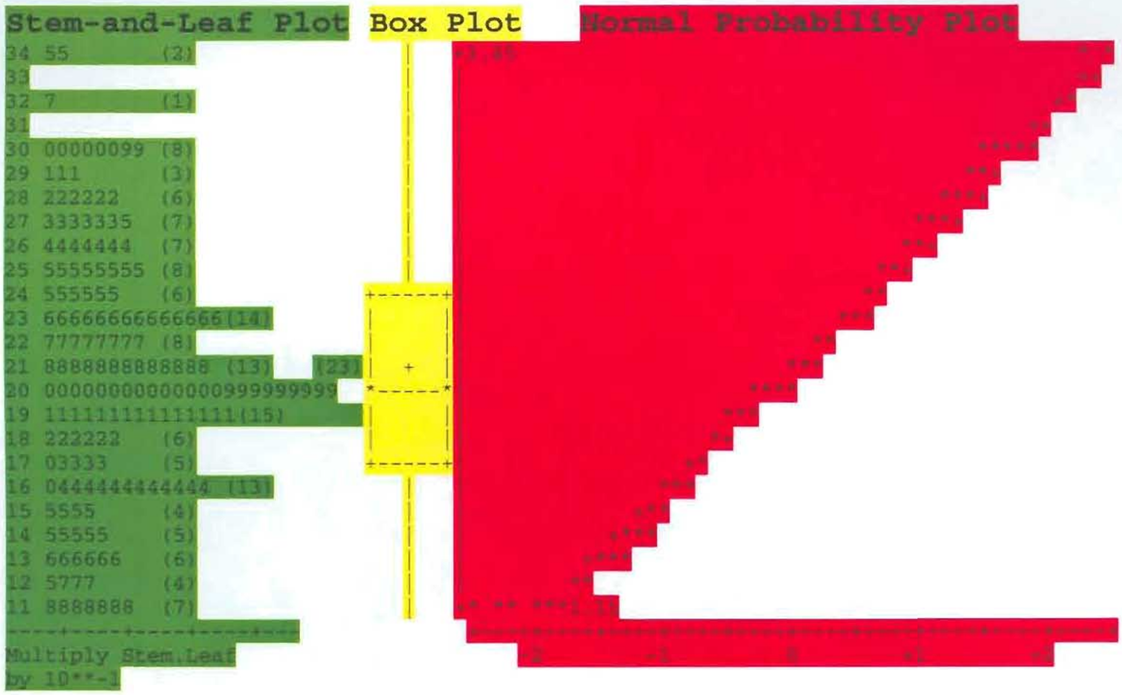

Figure 6.1. Frequency Plots of Technological Literacy Scores

The stem-and-leaf plot can be interpreted as a bell shaped curve which is positively skewed, thus showing that the data is not perfectly normally distributed. The mode and the main peak of the curve are at a score of 2.09, with a frequency of 23. The main or central peak extends over a range of scores from 1.8 through to 2.4, and there are two smaller peaks on either side of the central peak base at scores of 1.6 and 3.0. Although the Stem Leaf is not perfectly shaped for a normal distribution, the shape does tend towards a near normal distribution.

The box plot also suggests an imperfect distribution of the data of technological literacy scores, as the box is not equidistant between its two extremities. The box plot is positively skewed, as the mean is greater than the median.

The normal probability plot yielded almost a straight line indicating a near normal distribution of the data on technological literacy levels of the students. Therefore, although the data might be slightly skewed to the right (bottom in Figure 6.2.) as expressed in the stem-and-leaf and the box plot, it is evident that the skewedness is not extreme and the data on technological literacy levels of the students can be considered to be normally distributed. Of course, the data will not be perfectly distributed but the shape of the curve in the normal probability plot does approximate to normality.

The above analysis of frequency plots contributed to an objective assessment and acceptance of the near normal distribution of the data. Thus, parametric tests can be applied to the data. The analysis of technological literacy levels of the cohort of students that experienced traditional science curricula at school follows.

6.4. Analysis of Technological Literacy Levels of the Selected Cohort of Science Students

This section of the chapter will address critical question three, namely, what were the levels of technological literacy in the selected cohort of undergraduate science students?

To determine the levels of technological literacy of the students, the following method was employed: There were six questions on technological literacy. Some of these questions consisted of multiple parts. Hence, there were eleven sub-questions on technological literacy, which corresponded to eleven variables (V23, V25, V27, V29, V31, V33, V38, V43, V48, V53, & V55). Each student scored between 1 and 5 points for each of the eleven variables. For each student, the mean of these 11 scores was calculated, and the students were classified 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

(X represents the mean of the scores for the 11 variables, and each of the above classifications is consistent with the SOLO Taxonomy as described in chapter three. The range of scores here was between 1,18 and 3,45. Thus there were no students in the X = 4 or 5 category.)

As mentioned above, the scores for technological literacy were not whole or natural numbers and the range of scores were from 1,18 through to 3.45. Each of the technological literacy test scores was then converted to a whole number, and the acronym RTOTT is the rounded technological literacy test score. The distribution of students' rounded scores for technological literacy were as follows:

Technological Literacy or RTOTT	Frequency	Percent
1	22	12.9
2	107	62.6
3	42	24.5

Table 6.3. The General Distribution of Students' Scores for Technological Literacy

Table 6.3. shows that the most frequent rounded technological literacy score was 2. Almost 63 % of the students scored a rounded technological literacy score of 2. These students were at the unistructural level of the SOLO Taxonomy.

A small percentage of the students (almost 13 %) scored a rounded technological literacy score of 1. These students were at the prestructural level of the SOLO Taxonomy.

A mediocre number of students (almost 25 %) scored a rounded technological literacy score of 3. These students were at the multistructural level of the SOLO Taxonomy.

Note that although a student may have a rounded technological literacy score of 1, 2, or 3, it does not imply that all the responses provided by the student to all the technological literacy variables were the same. For example, a student may have a rounded score of 2 but have some responses at higher or lower levels of the SOLO taxonomy. There were even some students who scored 4 or 5 on some of the eleven sub-questions related to technological literacy but their mean scores were 3. A discussion on the detailed distribution of technological literacy scores follows.

Table 6.4. below illustrates the detailed distribution of students' scores for technological literacy. The acronym TOTT is used to abbreviate the true (not rounded) scores for scientific literacy. The FREQ Procedure data were used to generate Table 6.4.

Technological Literacy Score or TOTT	Frequency	Percent
1.18	7	4.1
1.25	1	0.6
1.27	3	1.8
1.36	6	3.5
1.45	5	2.9
1.55	4	2.3
1.6	1	0.6
1.64	12	7.0
1.7	1	0.6
1.73	4	2.3
1.82	6	3.5
1.91	15	8.8
2	14	8.2
2.09	9	5.3
2.18	13	7.6
2.27	8	4.7
2.36	14	8.2
2.45	6	3.5
2.55	8	4.7
2.64	7	4.1
2.73	6	3.5
2.75	1	0.6
2.82	6	3.5
2.91	3	1.8
3	6	3.5
3.09	2	1.2
3.27	1	0.6
3.45	2	1.2

Table 6.4. The Detailed Distribution of Students' Scores for Technological Literacy

As revealed in Table 6.3. the technological literacy scores of the students were confined to the prestructural, unistructural and multistructural levels with rounded scores of 1, 2 and 3 respectively out of a total of 5. None of the students were able to score at the relational or extended abstract level which required mean scores of 4 and 5 respectively out of a total of 5. Table 6.4. magnifies the distribution of prestructural, unistructural and multistructural scores, i.e. in the prestructural range the scores were between 1.182 and 1.455, in the unistructural range the scores were between 1.545 and 2.455, and in the multistructural range the scores were between 2.545 and 3.455.

Thus, for each of the demonstrated levels of technological literacy, there was a spread of the scores across a continuum. So, a rounded technological literacy score of 2 should not be narrowly interpreted as such, but could lie anywhere between 1.545 and 2.455. Simply stated, the rounded technological literacy scores are used for convenience and that should always be borne in mind.

The categorization of students using prestructural, unistructural, and multistructural labels led to the identification of the students in each of these groups. The three groups of students' scores were compared with their scientific literacy scores to establish if there were similarities in the two sets of scores. Table 6.5. shows the overlap of the students with corresponding scientific and technological literacy levels.

Category	Scientific Literacy Level	Technological Literacy Level	Number of Students
1	Illiterate	Prestructural	5
2	Mediocre	Unistructural	32
3	Good	Multistructural	20
4	Excellent	Multistructural	14
			N =71

Table 6.5. Combined Scientific and Technology Literacy Levels of Students

A total of 71 students (42 %) of the students had corresponding scientific and technological literacy scores. Note that ideally an excellent scientific literacy score would correspond with a Relational SOLO taxonomy status for technology. However, because there were no rounded technological literacy scores of 4 (relational type), students with excellent scientific literacy and multistructural level of technological literacy were combined for convenience.

The categories that featured in Table 6.5. above formed the basis of identifying selected students who were interviewed to corroborate claims made in the questionnaire and for the qualitative analysis of responses to the six questions on technological literacy which follows.

The qualitative analysis of the six questions on technological literacy provides a portrait of the patterns and qualitative differences in the responses of different categories of students. This is a new dimension in the analysis of the technological literacy levels of the students. One feature of the data that is of paramount importance in the analysis of technological literacy data is to understand that if a student falls within any category, e.g. category 2, there could be a mixture of pre-, uni- and multi-structural responses in any of the categories. The analysis that follows will therefore engage the categories as such. The reader is encouraged to review the questionnaire (Appendix 1) in tandem with the analysis which follows, where necessary.

6.4.1. Analysis of Responses to Technological Literacy Question One

The first question on technology addressed specific outcome three (SO3) in the technology learning area, namely: access, process and use data for technological purposes.

The corresponding task was:

The graph below (see Appendix 1 for figure of graph) 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. Provide reasons for changes to the shape of the graph:

The graph reflected a consumption of 1000 to 1300 units per month for the three-month period. The solution to the problem required an explanation of the impact of seasonal change (winter to summer) on electricity consumption. This rationale could then be translated into sketching a new graph for the period December through to February at a lower level of electricity consumption and explaining its shape.

6.4.1.1. Category One Students' Responses to Technological Literacy Question One

Contradictions and confusion characterized the category 1 students' responses. The responses also exhibited the prestructural characteristics predicted by Biggs & Tefler (1987), as the outcomes were inadequate or simply incorrect.

Simply incorrect responses, for example, ignored seasonal changes as a cause of the lower consumption of electricity, but linked people going on vacation exclusively to lower electricity consumption. The same student (2002380) went on to contradict this claim of lower consumption by reflecting an increased consumption of electricity in the period December through to February. One student (2008802) in category 1 even went as far as saying that consumption of electricity is lower in winter. This student went on to contradict this incorrect claim by showing equivalence in the electricity consumption between the winter and the summer months.

Another student (9927847) had no clue about how to interpret graphs: "...from jun to jul (sic) the graph decreases..." This student went on to reflect the electricity consumption for the Summer months as higher than the Winter months, and at a constant level in each of the Summer months. Yet another student (2012758) was very confused about seasonal times: "The electricity consumption would be higher in December (to) February than in May (to) July; because it's Winter (December (to) February) and things like heaters etc be used; which would increase the electricity consumption." This student went on to reflect higher electricity consumption in the summer months. A different student in category 1 (2028748) avoided answering the question by stating the relationship between the shape of the graph and the consumption of electricity. This was interesting as it raised expectations about the shape of the graph that would be drawn by the student. However, the student showed equivalence between the electricity consumption in the two periods.

The above analysis of category 1 responses shows that the access, process and use of data for technological purposes by these students is poor. It would be interesting to see the qualitative differences in the nature of responses by students in categories 2, 3 and 4. A discussion of responses from these categories follows.

6.4.1.2 Category Two Students' Responses to Technological Literacy Question One

One would expect a distinct shift in category 2 students to a general higher order of thinking; however, that is not necessarily the case. There is a distinct combination of responses in this category of students, some lower order responses and some higher order responses.

Lower order responses were of four types. First, some students sketched a near equivalence between the consumption of electricity in Winter and Summer, and corroborated their misunderstanding with statements like "…the electricity will automatically go higher, the same as May, June and July" (2006050). Second, some students (2000972) attributed the lower consumption of electricity in the period December through to February exclusively to the family going on vacation for three months. Third, some students were on the opposite extreme and predicted an increase consumption of electricity because of people staying at home during the holidays: "In December the electric (sic) consumption is too high because December is a school holiday month and so the kids might spend the rest of the day in the house using electric equipment..." (9927681). Fourth, some students contradicted themselves by reflecting a high consumption of electricity on the graph for the period December but arguing convincingly in the narrative that the consumption is lower in the period December through to February. Across these four types of lower order responses were many instances where there was a distinct silence on seasonal differences.

There were three conspicuous features of the higher order responses in category two. First, there was a greater degree of correspondence between the narrative and the graphical representations that were made. Second, some students emphasized that the use of heating appliances for warmth, and additional lighting for longer nights, results in greater electrical consumption in winter. This scenario was then contrasted with that in summer, and a lower consumption of electricity was justified. For example, "During the summer seasons the day is very long and the night is short then the lights won't be in much use. During winter the night is very long with short time of the day then electric lights will be in more use and the heaters will be lit for warmth. Then there will be much consumption of electricity" (2021062). Third, there was a rationale for the differentiation of the electricity consumption levels in December, January and February. For example, "December – Electricity used will be less than other (two) months, because most people go on holiday and then only the lights are burning. January – It will increase but only from the middel (sic) January because that is only when the people are back. February – Will increase rapidly because students/children stay up later to study etc" (2012596). In general, the responses of category 2 students were more coherent than those of category 1 students. The discussion of category 3 responses follows.

6.4.1.3. Category Three Students' Responses to Technological Literacy Question One

In the introduction to the analysis of technological literacy levels of students it was mentioned that if a student falls within any category, e.g. category 2, it implied that the mean score for that student was 2, and not that all the scores were 2. So, there could be a mixture of pre-, uni- and multi-structural responses in any of the categories. This has been the case for the foregoing two categories but not necessarily with category 3. A greater consistency prevails in category 3 with most of the students being at the multistructural level. However, there were a few students with prestructural and some with relational understandings.

This preamble to the analysis of category 3 has highlighted the first conspicuous feature of category 3, namely: a greater consistency in the responses. There are other noticeable features of this category 3 as well. These features are elaborated below.

First, the students in category 3 responded immediately with a justification of the graph based on seasonal differences. For example: "Since the months December, January and February are in summer, less electricity is being used. In May, June and July it was autumn and winter season so the use of electricity increased due to the extensive use heaters, kettles and such. It would therefore be logical for the use of electricity to be lower during summer" (2009582).

Second, almost all of the students in category 3 are able to sketch changes to the graph correctly, and justify their sketches in the narrative. Therefore, contradictory statements were uncommon.

Third, there is also a greater level of coherence in their narrative descriptions, almost to the extent that the narratives a relational status of the SOLO taxonomy where the learner now integrates the parts with each other so that the whole has a coherent structure and meaning. For example: "December – February is summer. Lights are turned on for shorter periods of time. The only appliance that uses much electricity in this time is the refridgerator (sic). No great need for warm water or food" (2015226).

Finally, as with category two, some students felt the need to differentiate between energy consumption in each of the months from February through to December and explain the changes in consumption. The rationale differentiation and explanations are similar to those in category 2 students.

The category 3 students thus far represent the highest level in the quality of responses to the question on accessing, using and processing data. It would be interesting to see how category 4 students' responses differ in substance, and quality, from category 3, if at all.

6.4.1.4. <u>Category Four Students' Responses to Technological Literacy Question One</u>

Just a reminder to the reader that category four students include those with excellent scientific literacy and multistructural technological literacy as indicated in Table 6.5. Category 4 students provided terse but coherent responses. The terse nature comes through with short statements and the use of mathematical signs: "consumption reaches low point during December (warmest time of the year = less heating of water, more daylight = less use of lighting" (2014398). The coherence is illustrated in: "Electricity consumption is less because its summer and less energy is required for the heating of the home and the nights are shorter, so less energy is needed to light the home" (9915905).

Almost all the students in category 4 sketched changes to the shape of the graph for summer correctly. Additionally, category 4 students provided a greater level of detail in their narrative: "Consumption will be at its lowest in February because it is the hottest month of the year..." (9928559). Moreover, there was also a greater depth to the responses in category 4: "In the winter people use more electricity when... (they) turn up the thermostat of the geyser so that the water is warmer" (2003356).

6.4.1.5. <u>Summary of Responses to Technological Literacy Question One</u>

Thus, the responses to the question on access, process and use of data has evolved from category 1 with simply incorrect or inadequate responses with high levels of contradiction, to category 2 with a combination of lower and higher order responses and some contradiction, to category 3 with a greater consistency and coherence in the responses, to category 4 with short statements and the use of mathematical signs in developing coherent arguments. The same type of analysis follows for the second question on technological literacy.

6.4.2. Analysis of Responses to Technological Literacy Question Two

The second question of technological literacy related to specific outcome 4 (SO4) in the technology learning area, namely: select and evaluate products and systems.

The corresponding task was:

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

The above task probed the technological savvy of the students to understand the technological factors that informed their decision-making process when purchasing a product of technology, i.e. a cell phone. The correct responses to this question would entail not simply a list of technological features but the linking of these factors into a coherent whole. There was; however, some variety in the nature of the responses as outlined below. Once again the responses are grouped by category.

6.4.2.1. Category One Students' Responses to Technological Literacy Question Two

Category 1 students were either incorrect, avoided answering the questions, or focused on irrelevant information. A typical example of focusing on irrelevant information was a set of definitions on waves, conductors, 'senders', and cell phones. Category 1 students responses were also inadequate with a focus on commercial factors like: "Determine if you want a pay-as-you-go or a contract..." (2012758). The same student also focused on irrelevant information, i.e. outlined the merits of cell phones as communication devices which do not require wires: "...wires don't have to be connected to your cell phone in other (sic) to use it".

There was also incoherence in the responses provided by category 1 students. For example, some responses restated the question as in: "Look at the technological method of the cell phone" (9927847). This same student went on to state: "...It will help me in difficult situation (sic)" thus being ambiguous rather than outlining the fact that cell phones have free access to emergency services. There was also a hint of some knowledge of technological features of the phone from the same student who stated: "This is access to the Internet or any other place like over the water," suggesting that cell phones allow us to access to the information and communication.

6.4.2.2. Category Two Students' Responses to Technological Literacy Question Two

Category 2 students' responses were a combination of mediocre and poor types.

Mediocre responses included a list of technological factors like good reception and network coverage but did not attempt to integrate the list of factors and bring any coherence to the response. Good reception, for example, was intimated in statements like: "That its frequency wouldn't affect or be affected by the environment..." (2028176). There was, however, no attempt to link this feature of good reception to other technological factors like network coverage.

The slew of technological factors listed by category 2 students included battery quality, size and weight of the phone, and features like calculators and alarm clocks (2025350). Other technological features that were prominently featured amongst the mediocre responses were text messages, caller identity, and network coverage (9917181), picture messaging (2013886), durability (2021062), battery life (2001546), memory function to save phone numbers, games (2016474), and fax information, mail box functions (2006806). There was just one response in category 2 with some depth: "They have a lot of disturbance to electronic things like radios, TVs, etc," thus alluding to the concept of interference (2013986).

Poor responses were commercial in nature and included: "The amount charged for getting connected" (2000972). Other responses in this category contained irrelevant information like: "...there must be a need for a phone" (9811761). Some students provided no response at all (9828433).

6.4.2.3. Category Three Students' Responses to Technological Literacy Question Two

Category 3 offered more refined responses than their counterparts in categories 1 and 2. There was still a list of technological factors [durability (2001832), picture messaging (2015226), level of radiation (2004006), memory and phonebook facilities (2007470)] presented without integrating the response into a coherent whole. Nonetheless, the factors were enhanced with use of labels such as ergonomics (2003744), stand-by time (2003088), talk-time, re-charge time (2009582), security features (2006448), and a vibrating ring (2020082). Unequivocally, these students in category 3 were at a higher conceptual level of understanding than their counterparts in categories 1 and 2. This higher conceptual knowledge manifests itself in the superior list of technological features of cell phones provided by students in category 3.

Moreover, there were technological features that surfaced from category 3 students that were not mentioned by students in the first two categories. For example, "WAP (wireless application protocol) web access ... to access the Internet using a cell phone, not a personal computer" (2020082)/(2021378). Greater depth of understanding also featured in comments by students in category 3 that pertained to dual and tribands, as well as to "data modems and international roaming" (2013456). Apparently, "a dual band can operate on both GSM frequencies - 900/1800" (2022118), and a "tri-band cell phone can be used in Europe and America as well as in South Africa" (2007790). Students in this category also talked about using a cell phone for data transfer to a personal computer (2015226), and "using a Lithium-Iron battery that does not lose its battery (sic)" (2021378).

Other new features that surfaced in category 3 included students questioning the availability of "hands-free options, car kits" (2010060). This same student then went on to question whether the cell phone properties could be extended to a normal phone.

6.4.2.4. Category Four Students' Responses to Technological Literacy Question Two

Category 4 students' responses were similar to those in category 3 in that a list of technological factors was presented without being linked in a coherent fashion. As with category 3 students, this list was improved with labels that demonstrated an understanding of technological features of a cell phone. For example, dual networking capabilities for better reception (2011896), and the routine features of battery life span, memory size, stand-by time, fax, email and internet facilities, SMS, and good reception. Additionally, like category 3 students, category 4 students also elaborated on "WAP enabled, Dual Band 900/1800 (features)" (2011612) and followed through with explanations of these kind of features. The new (not mentioned in the previous three categories) technological features of a cell phone that surfaced in category 4 students included voice recognition (2014074), as well as protection against radiation and a discharge function to protect the battery.

6.4.2.5. Summary of Responses to Technological Literacy Question Two

Thus, the responses to the question on selecting and evaluating products and systems, by describing the technological features of a cell phone, were varied. The responses progressed from category 1 students who were either incorrect, avoided answering the questions, focused on irrelevant information, or incoherent, to category 2 students' responses which were a combination of mediocre and poor types. Mediocre responses included a list of technological factors like good reception and network coverage but did not attempt to integrate the list of factors and bring any coherence to the response. Lower order responses were commercial in nature or contained irrelevant information. Category 3 offered more refined responses than their counterparts in categories 1 and 2. Category 3 students still provided a list of technological factors but enhanced the list with the use of labels like ergonomics. Category 4 students' responses were similar to those of category 3 students. The same type of analysis follows for the third question on technological literacy.

6.4.3. Analysis of Responses to Technological Literacy Question Three

The third question on technological literacy related to specific outcome 6 (SO6) in the technology learning area, namely: demonstrate an understanding of the impact of technology.

The corresponding task was: *Discuss the impact of the Internet on society:*

This particular task was challenging in that it focused on impact, which is very different from interpreting data (task 1) or describing technological features (task 2). In fact, this task required an understanding of how a technological device has influenced our daily lives. Once again, the idea was simply not to elicit a variety of impacts but to test whether the information presented could be integrated and linked into a coherent whole. The analysis follows below.

6.4.3.1. Category One Students' Responses to Technological Literacy Question Three

Category 1 students' responses were, with the exception of one student who simply restated the question focus (2002380), generally better than for this task as compared to tasks 1 and 2. The responses of category 1 students were generally correct and adequate. Category 1 students listed a variety of impacts of the Internet on society.

Some of the impacts listed by category 1 students were simple like access to information: "...our generation will get to know about other countries..." (9927847), or "there is no need to go to the library to get information for a task you can just type in a topic and pages of information appears (sic) on the screen" (2008802). Others in category 1 listed expeditious communication as an impact: "They will be able to communicate with people...to send e-mails without the waste of time of posting it" (2028748). Some students in category 1 focused on commercial and practical benefits like shopping from home instead of "getting in the car and drive to do the shopping (sic)" (2012758), or banking and payment of accounts on the Internet.

One student went beyond the simple impacts of access to information, expeditious communication, and commercial and practical benefits, to talk about the social evil of the internet in that it is a cause of unemployment: "With the internet many people don't have work anymore" (2008802). Therefore, inasmuch as the Internet is seen as a benefit to society, it is also has demerits like threatening job security.

6.4.3.2. <u>Category Two Students' Responses to Technological Literacy Question Three</u>

Category 2 students' responses amplified the educational merits, the undesirable content, and the risks associated with the Internet, as discussed below. They also listed the routine merits of the Internet as outlined by students in category 1. These routine features of the Internet included: access to information, expeditious communication, and commercial features like banking and shopping or business transactions. One new feature of the Internet that surfaced amongst category 2 students was the advertising potential of the net: "it's a cheaper way of trying to sell your product" (2014878).

The education merits of the internet, as outlined by category 2 students, included its positive impact on "research and projects..." (9915173), "it enhances research capabilities for a wide range of people" (2016474). Additionally, the Internet was seen to enhance computer literacy as it "forces people to get to know how to use computer and Internet" (2002410). Moreover, one category 2 student believed that the Internet has "made distance learning far easier" (9917181).

The undesirable content of the Internet included pornography and instructions on how to develop destructive devices. For example, students felt that the Internet introduces "...ponography (sic) to those (whom) it is not eligible to, like children" (2008020). The same student went on to elaborate on the destructive nature of the internet content by citing the free access to drug formulas that can be harmful to students if experimented with. The instructions for developing destructive devices was echoed in the statement: "...it now enables kids to get instructions to bombs..." (2011966).

There are various risks associated with using the Internet. Some of the students believed that "...people spend more time on the net and less time with their families" (2017578), or that "it (internet) has turned children into zombies, they do nothing but 'surf the web' the whole day" (2013886). Yet another risk includes: "...children communicate with people they don't know and they give them the home addresses and those people can come and steal from or make arrangements with kids and when they meet they kidnap them for money" (9927681). The latter scenario is not a figment of the student's imagination. According to the student, it is a fact that was lifted from a reputable television talk show that discussed the Internet.

6.4.3.3. Category Three Students' Responses to Technological Literacy Question Three

Category 3 students' responses were generally very similar to those in category 2. In fact, unlike other tasks, it was difficult to establish the higher level of thinking associated with this group of students for tasks 1 and 2. There were, however, a sprinkling of well-informed responses which elevated category 3 responses to those in categories 1 and 2, e.g. "The internet has led to a decentralization of business as people can now work from home" (2010060). Moreover, the superiority of some of the responses in category 3 students manifested itself in the use of labels like e-commerce, virtual libraries, chat rooms, on-line game playing, improved global awareness, as well as "fraud and computer hacking (which are) now abundant on the internet" (2027440).

Of course, common responses, as listed in category 2, were plentiful in category 3. These common responses included, amongst others, descriptions of the Internet as: a powerful and faster means of communication, readily accessible information, banking facilities, shopping. Some of the ideas of category 2 students were reiterated like improved research as a result of access to literature on the net. Also, the negative social impact of the internet like exposure to pornography and the construction of explosive devices like bombs (2009940) were emphasized by some students in category 3. The students did however, expand on this latter concept of pornography and talk about child porn or paedophilia (2003744) as a disgusting feature of the net. Social degradation also featured as a negative impact of the Internet amongst category 3 students: "Although it (Internet) has brought people together via conversation, personel (sic) interaction is still sorely missed and may lead to a disfunction (sic)" (2010060).

6.4.3.4. Category Four Students' Responses to Technological Literacy Question Three

Category 4 students' responses were not impressive, as they did not provide the elaborate understandings anticipated of them. Rather, the nature of category 4 responses was similar to those of category 3 students. In fact, had it not been for the use of interesting descriptors like "globalized the marketplace" (9928559), category 4 responses could have been relegated to category 2 status. The responses in category 4 were also suffused with the regular descriptions on the impact of the internet like it being a limitless source of information, ease of communication, facilitation of business especially for small business, and serving as a reference library. Students in category 4 also alluded to the social impact of the Internet as "pollution of innocent minds" (2015468), and the Internet being the cause of "new kinds of crime and new opportunities for fraud" (2014398). The only new feature of this set of responses from category 4 was the displacement of the television by Internet: "(The Internet has) taken over the number 1 role for passive entertainment from the TV" (9915905).

6.4.3.5. Summary of Responses to Technological Literacy Question Three

Thus, the responses to the question on SO6 in the technology learning area, namely: demonstrate an understanding of the impact of technology, using the question related to the impact of the internet on society were not as varied as was the case with the two previous tasks. Category 1 students listed impacts, which were simple like access to information, expeditious communication, and commercial and practical benefits. There was also a focus on social ramifications of the Internet like being a cause of unemployment. Category 2 students' responses amplified the educational merits, the undesirable content, and the risks associated with the Internet. They also listed the routine merits of the Internet as outlined by students in category 1. Category 3 students' responses were generally very similar to those in category 2. There were, however, a sprinkling of well-informed responses, like the use of e-commerce features of the Internet that elevated category 3 responses above those in categories 1 and 2. Category 4 students' responses were similar to those of category 3 students. A similar analysis will now unfold for the fourth question related to technological literacy.

6.4.4. Analysis of Responses to Technological Literacy Question Four

The fourth question on technological literacy related to specific outcome 7 (SO7) in the technology learning area, namely: demonstrate an understanding of how technology might reflect different biases, and create responsible and ethical strategies to address them.

The corresponding task was: *Should the drug AZT be made available to pregnant women in South Africa ?*

To provide a response to this question required an understanding of the high incidence of transmission of the HIV/AIDS virus from mother to infant, and the corresponding solutions to this form of transmission of the virus. AZT was one of the popular drugs in 1999 and 2000 used for the purpose of preventing the transmission of the virus from mother to offspring. Recently, the new drug, Nevirapine, has proved to have the same effect with greater success. Despite the evidence about reduced transmission rates while using either drug, the South African Government remained adamant that it would not support the provision of the drugs, even if they were made available at low cost to the government. The difficulty in answering this question lay in the fact that it was not taught in the Life Sciences syllabus and required that one extend beyond the school curriculum into real life challenges.

6.4.4.1. Category One Students' Responses to Technological Literacy Question Four

Category 1 students' responses were inadequate. The students either did not respond (2012758, 2028748) or admitted having no understanding of the drug AZT (2008802). One student (2002380) intimated no understanding of the drug by rejecting the drug and stating: "it would be a bad influence on the child and also the mother..." Another student recommended trialing the drug before providing it to pregnant women in the interests of safety, but did not show any understanding of the impact of the drug on the foetus.

6.4.4.2. Category Two Students' Responses to Technological Literacy Question Four

Category 2 students' responses were of three types: 1) a combination of informed answers which reflected some understanding of the drug and its use; 2) responses which were purely speculative or in which students admitted having no clue about what the drug; and 3) responses which defended the government's standpoint on not making the drug available to pregnant women.

The informed responses were terse and clearly demonstrated an understanding of the use of the drug. For example, "Yes, it should be made (available) to reduce the risk of unborn child for HIV/AIDS (sic)" (9828433). One student (2016474) justified why the drug should not be provided to pregnant women by stating that "...AZT cells, good or bad, it does not select just the infected cells, but kills good ones as well and in the end might affect the child." Another student (2028176) supported the use of the drug and implicitly demonstrated an understanding of the use of the drug by stating that the drug would prevent children from dying. This student also mentioned the subsidization of the drug by foreign countries like America, which would make the drug more cost-effective. Others supported the use of the drug for scientific reasons, e.g. "Yes, because the scientist had tested it and found that it protect the infant from being infected by virus (sic)" (2011728). Some of the answers went beyond the prevention of HIV/AIDS to focus on care of the child. For example, one student (2001546) knew that the child would survive and not the mother and questioned whether bringing a child up without a mother is desirable. The same student proposed that the money should be used to help educate people avoid contracting the disease.

Those students who speculated incorrectly made claims that AZT was used for abortions (2017528, 2013986, 2014878). Other speculative responses pertained to claims by students that drugs could have a bad influence on pregnant women (2006050), others stated that the drug can affect the baby (9828451) but did not elaborate, another group mentioned that it would help to save the mother's life at the expense of losing the child (2011966). Some students just felt that it was a matter of choice. Some students did not have clue about what the drug was capable of, and openly admitted this (9917181, 9915173).

Those students who supported the government's standpoint on not making the drug available to pregnant women, justified the approach for various reasons including high costs (9811761), or "because the department of health dismissed it because they seem that it is harmful to the person, so they don't want to make other people's life in danger" (9922393).

6.4.4.3. Category Three Students' Responses to Technological Literacy Question Four

Category 3 students' responses were generally coherent on whether AZT should be made available to pregnant women. Some students went beyond transmission issues to discuss impacts of the drug on society. A small number of students just speculated on why the drug should be made available and yet others were incorrect because they provided yes/no answers without a justification.

Many of the students were able to describe the effect of the drug AZT as a method of preventing the transmission of the HIV/AIDS virus from mother to child. The understanding of this concept by the students was either explicit or implicit. Explicit responses included: "Yes, …it should be given to pregnant women to reduce the risk of transmission of HIV from mother to child" (2015226), or "Yes, it will theoretically decrease the amount of HIV-positive people in the country" (2016252). The implicit understanding of transmission came through in statements like "the kid should be given a chance in life. Not die painfully. Aids (sic) is a serious issue" (2003088), or "Yes, the child is not responsible for the mother mistakes" (2004006).

The students in category 3 went beyond transmission issues to discuss impacts of the drug on society. This focus was also a feature of category 2 students' responses but was more amplified in category 3 students' responses. Students raised issues like "...if we prevent the spread from parent to child…when the child becomes a parent, the cycle will not be carried down the generations." (2011748). Another student (2022118) was concerned about side-effects of the drug: "No, the side effects may have been tested over two or a maximum of 5 years, but no one really knows what AZT will do to those children when they are perhaps twenty, or their children." Yet another student (2000222), was concerned that we the earth is approaching its carrying capacity of humans and that HIV/AIDS might be away of natural selection to reduce the population of mankind: "No,…AIDS is a way that nature will use to try prevent a problem with to (sic) many people,…if people died is big, then the population will grow less." Other students were concerned about the challenges associated with caring for orphans: "If the drug is administered to pregnant women, then their babies are born free of AIDS but the fact that the mothers of these children will soon die is often forgotten. These children end up as a burden to a family member or in an orphanage" (2009582).

There were also some speculative answers to the question on whether AZT should be made available to pregnant women. For example, "If this would prevent AIDS victims from transmitting the virus to their children, then yes" (2021378). Other purely speculative responses from students included justifications for providing the drug based on personal choice (2003744) or provided that additional research is undertaken (2013456).

6.4.4.4. Category Four Students' Responses to Technological Literacy Question Four

Category 4 students' responses were also a combination of well-informed responses, responses that justified why the drug should not be freely available, and simply speculative responses.

Well-informed responses were fairly explicit, showing good understanding of the potential of the drug AZT inhibiting mother-to-child transmission of HIV/AIDS. This knowledgeable set of responses included responses like: "Yes, if AZT is made available to (a) pregnant woman it would prevent the unborn baby to get the HIV" (2014074), or "...It (AZT) decreases the chances of the baby having aids/HIV (sic) very much (2011612), or "...by giving it to all people with aids (sic). The baby could have a better chance of surviving" (9909683).

As mentioned above, there were also responses, which justified why the drug should not be freely available. Some good responses as to why AZT should not be provided pregnant women included: "It could encourage more people to live recklessly" (9916081), or "No, studies has shown that AZT can be a dangerous drug by 'killing' you from inside-out. In fact, AZT was not developed for use for HIV-infected people" (2007642), or AZT should not be available because its side effects are still unknown (2011896).

Responses which were speculative in nature included: "As long as sufficient research has been done on the drug..." (9914891), or "Yes. After all, it's their choice" (9915905), or "If it could save lives yes, but not if it kills" (2003356)

6.4.4.5. Summary of Responses to Technological Literacy Question Four

Thus, the responses to the question on SO7 in the technology learning area, namely: demonstrate an understanding of how technology might reflect different biases, and create responsible and ethical strategies to address them, using the question related to making the drug AZT available to pregnant women, had a spread of responses from inadequate to superior. Category 1 students' responses were inadequate with students either not responding or admitting to having no understanding of the drug AZT. Category 2 students' responses were of three types: 1) a combination of informed answers which reflected some understanding of the drug and its use; 2) responses which were purely speculative or in which students admitted having no clue about what the drug; and 3) responses which defended the government's standpoint on not making the drug available to pregnant women. Category 3 students were generally able to provide coherent responses to the question on whether AZT should be made available to pregnant women. Some students went beyond transmission issues to discuss impacts of the drug on society. A small number of students just speculated on why the drug should be made available and yet others were incorrect because they provided yes and no answers without a justification. Category 4 students' responses were also a combination of well-informed responses, responses that justified why the drug should not be freely available, and simply speculative responses. The same kind of analysis now follows for the fifth question on technological literacy.

6.4.5. Analysis of Responses to Technological Literacy Question Five

The fifth question on technological literacy related to specific outcome 5 (SO5) in the technology learning area, namely: demonstrate an understanding of how different societies create and adapt technological solutions to problems.

The corresponding task was: *Provide an illustrated example of an indigenous (home grown) form of technology that you have experienced in South Africa.*

This task required the students to think about an example of homegrown technology that they have encountered in their daily lives in South Africa. The idea was not to elicit from them information about some high-tech invention but to get them to think about how have seen technology in action in their daily lives.

6.4.5.1. Category One Students' Responses to Technological Literacy Question Five

Category 1 responses were disappointing in that some students could not extend themselves to even list an example. Those students who did attempt to provide a response listed irrelevant information like the availability of water, electricity, televisions and computers today as opposed to the 'old days' (2002380) when these facilities or appliances were not available. Clearly this is a typical prestructural response because despite the fact that the task was engaged, the students were distracted or misled by an irrelevant aspect. Yet another response echoing this kind of preoccupation with irrelevance was: "TV is the best technology in our life, the screen of the TV, the sound" (9927847).

6.4.5.2. Category Two Students' Responses to Technological Literacy Question Five

Category 2 students' responses demonstrate that students' perceptions of technology are fashioned by products that are developed outside of their immediate environments. Indeed, the responses to the questions provided by category 2 students were irrelevant, largely inadequate or simply incorrect. The technological devices listed most commonly included recent technological appliances or devices (cell phones, generators, radios, satellite dishes, and sensors), recent advances in technology (local web-sites, computer programmes), or existing technological tools (trip switches, lights, windmills). Only one of the students in category 2 was able to provide an illustrated example of an indigenous (homegrown) form of technology that they have experienced in South Africa. The student provided the example of "the use of natural resources e.g. grass, mud, clay, dung to create insulated dwellings that have a large degree of permanence" (2011966).

6.4.5.3. Category Three Students' Responses to Technological Literacy Question Five

Category 3 students' responses were more elaborate than those offered by category 2 students. Nonetheless, the examples that were provided were generally not part of the daily experiences of the students. They had experiences at air shows or had read about or seen techno-gadgets that impressed them, and talked about them in their responses to this question.

Some of the examples provided category 3 students included: digital video broadcasting (DVB) which "allowed for digital compression and transmission of video" (2021378), the Infra-Red Mobile Lab (IRML) which detects heat sources by means of electronic equipment (2022118), the Rooivalk which is an "attack helicopter with its lazer guided machine gun" (2010060, 2011748), and a calculator that has been transformed into a device used by bushmen to track live game (20018320).

One of the real life examples provided was a "(water) wheel barrow" (actually it is a cylinderical drum) which is used to transport water and heat the water as well. Can be left in the sun to purify and then it is safer to drink" (2015226). This is actually an innovation from an African country but it has relevance in a rural context in South Africa. These kinds of innovations with technology are simple and yet practical. The merits of this device are amazing, particularly with the cholera virus spreading in parts of South Africa. By heating the water in the sun for 24 hours the cholera virus and other disease spreading organisms are eliminated.

Three students also mentioned the wind-up radio as a technological device, which they have had, experiences with. This device uses mechanical energy provided during winding to supply electrical current to the radio, a device which could bring educational programs and entertainment to areas where there is no electricity.

Some of the responses in category 3 were inadequate or just listed irrelevant information. Some of the inadequate responses included illustrations of a mini-bus or discussion of the first successful heart transplant in the world, which took place in South Africa.

6.4.5.4. Category Four Students' Responses to Technological Literacy Question Five

Category 4 students' responses were similar to those of category 3 students, with the exception of some ingenious responses. Of course, there were also some responses, which were simply inadequate. The routine examples, which were not part of their everyday experiences, included the Rooivalk helicopter, G6 and G5 cannons, recent computer programmes, and radar and avionic systems. Also, the examples that have significance in a rural context, were reiterated: the water barrow and the wind-up radio.

The ingenious responses included the making of a rotisserie braai driven by a tape deck of an old radio motor (20104074), and the prevention of coastal erosion by developing a buffer between land and sea with a substance called "dollosse" (2014398).

6.4.5.5. Summary of Responses to Technological Literacy Question Five

Thus, the responses to the question on SO5 in the technology learning area, namely: demonstrate an understanding of how different societies create and adapt technological solutions to problems, were interesting and included fairly simple responses like the wind-up radio to more complex examples of the Rooivalk. Category 1 responses were disappointing in that some students could not extend themselves to even list an example. Those students who did attempt to provide a response listed irrelevant information. Category 2 students' responses were irrelevant, largely inadequate or simply incorrect. Category 3 students' responses were more elaborate than those offered by category 2 students. Nonetheless, the examples that were provided were generally not part of the daily experiences of the students. Category 4 students' responses were similar to those of category 3 students, with the exception of some ingenious responses. Of course, there were also some responses that were simply inadequate.

6.4.6. Analysis of Responses to Technological Literacy Question Six

The sixth and final question on technological literacy related to specific outcomes 1 and 2 (SO1 and SO2) in the technology learning area, i.e.:

SO1. Understand and apply the technological process to solve problems and satisfy needs and wants.

SO2. Apply a range of technological knowledge and skills ethically and responsibly.

The corresponding task was:

Suppose that the University of Pretoria decided to embark on an active campaign of community service and enlisted the support of its students. You have been requested to assist with resolving sanitation problems at an informal settlement for a population of 100 residents. You have the daunting task of applying your knowledge and understanding of sanitation issues to develop a system that is cost effective and convince the local community that the system that you develop is in their best interest. Prepare a detailed description of how you would approach this challenge. Your response should be restricted to a page and include details on:

Investigations Pursued:
Design and Planning:
Modifying Systems to Suit Contexts:
Sensitivity to the Issues and Choices in the Community of Informal Settlers:
Final Recommendation:

This question required a careful analysis of the state of sanitation at the settlement, and the subsequent development of an intervention to resolve the challenges in accordance with the steps identified above. The sequence of steps was derived from the suggested sequence in the Technology learning area as outlined in the Discussion Document of C2005 (DOE 1997a).

6.4.6.1. Category One Students' Responses to Technological Literacy Question Six

Category 1 students demonstrated an eagerness to answer the first two components of this question, namely investigations pursued, and design and planning. Thereafter their interest waned and they provided irrelevant or no responses. Some of the responses to the first two components were also either irrelevant or simply a repetition of the information in the question. For example, "I'll plan and design very well for it is a big task" (2008802). However, other responses to the first two components were impressive. Some students (2002380) started investigations very positively stating that they would first identify the worst spots in the area. Others (2028748) focused on aspects like population size, coping strategies, solutions provided by the community. The design and planning sessions recommendations included setting up a poster, and calling a meeting of the residents to let the informal settlers know that other residents are concerned about them (2002380). Another student (2012758) suggested that fines should be issued to enforce cleanliness, and that more people must be engaged to keep the bathrooms clean. One student (2028748) wanted to schedule visits and use a group approach to solve problems.

As mentioned above, the remaining three components of this question: modifying systems to suit contexts; sensitivity to the issues and choices in the community of informal settlers; and the final recommendation, had mostly no responses, or the occasional irrelevant answer or a repetition of information from the question. The only sensible answer to the sensitivity component was a response which emphasized that one should "let the community decide what to do" (2002380), thus showing an appreciation for the way the locals feel about solutions.

6.4.6.2. Category Two Students' Responses to Technological Literacy Question Six

Generally, category 2 students' responses were more refined than category 1 students' responses. Some students exhibited the general pattern of category 1 students because they answered the first two components of the question and simply ignored the remaining three components. The responses of category 2 students to all the components of question six will be discussed below.

In the component on investigations pursued, there was a combination of responses on a continuum from inadequate through to impressive. Inadequate responses included those with irrelevant detail or simply inadequate responses e.g. the exploration of a "high HIV rate" (2028176), which has no relevance to this situation of poor sanitation. Better responses entailed conducting a reconnaissance in a variety of ways. Some students proposed to "approach the experienced individual(s) for their guide" (2012418), others wanted to observe the settlement to examine, what kind of rubbish is present the most and what are the possible causes of these problems, the sources of water, number of waste disposal sites, and how many toilets need to be built, and the kind of facilities that would be suitable.

Some of the impressive methods of investigation included: "Is the cause of the problem lack of access to facilities or negligence" (2010106), "no toilets, no running water, no refuse removal, identify each one and see the seriousness of the impact on the population" (2016474). Another student (2011966) explored "potential diseases, costs of improving facilities, examination of existing drainage sewers and pipelines." Many of the students focused on the cost effectiveness of proposed solutions. The solutions offered to cost related challenges included the identification of sponsor companies

In the component on design and planning, cost-effectiveness was a pervasive component. Many of the students in category 2 were in favour of getting the community involved and wanted "to enlist support of people to clean up, insert facilities and running water, and get refuse removal" (2016474). The responses can be labelled as inadequate, routine, innovative and impressive. Inadequate responses included those that persisted with irrelevant detail like the "HIV focus" (2028176) or simply provided a restatement of the question. Routine responses entailed plans to "build new structures near sewers and drainage, ample supply of water, taps and basins" (2011966), or provide a sufficient number of trashcans and a refuse collection service. Other students wanted a proper bath and toilet facility for everyone or a good piping layout. Yet another student (2000972) proposed: "I would put portable sanitary toilets everywhere they are needed."

Innovative responses included an advocacy campaign with posters and pamphlets. One student (2013936) encouraged a partnership between private companies and the local community to integrate solutions offered into one plan. Another innovation proposed that the community should, "build toilets higher than ground level to prevent overflow of the toilets" (2014878).

Impressive design entailed assumptions like if there are 4 people per family then 100 residents would require 25 toilets. The students also proposed that the toilets should be positioned according to household locations and appropriate sewerage pipes. Other impressive responses focused on quality and aesthetics. The emphasis on quality was qualified as a need for good plumbing and fitting facilities. Others were keen on the need for "durable" toilets and good sewerage facilities. With regard to aesthetics, one student (2002488) stated categorically that: "The result must be aesthetically pleasing, daily cleaning must take place, maintenance must be ongoing."

The component on modifying systems to suit contexts was generally poorly answered by category 2 students with the exception of the odd, meaningful response. By and large, students in category 2 either provided irrelevant or inadequate responses. Some of the students even repeated the questions as a response. The few meaningful contributions included the "introduction of running water and toilets" (2008020), the development of an "underground pipeline to a sewerage farm, all water levels are lower than the facilities, therefore no overflowing" (2014878), and a concern about durability in that "facilities must be built to last e.g. tough and practical ablutions" (2011966). One student even suggested the establishment of a dumping site for the community.

Students in category 2 also provided poor answers to the component on sensitivity to the issues and choices in the community of informal settlers. Just under half of the students either did not answer or provided irrelevant answers, e.g. "order should be there" (2013986). Some of the students were also very instructive towards the community: "tell them exactly what is happening" (2001546).

Most of the remaining students were keen on engaging the community by listening to their complaints, opinions, views and beliefs. Two of the students emphasized that the solution must be convenient or appropriate for the community. Students were also sensitive to the limitations of the community and this was expressed in statements like: "They don't really have the money to buy…" (2017578). One student appreciated the involvement of the community but emphasized the need to remain within the budget.

The final recommendation component of the question was also poorly answered with more than half the students providing no response and irrelevant or inadequate responses. The remaining students provided a few average, and a variety of satisfactory, final recommendations.

The average or standard responses were pertained to the installation of taps every 5km, and building about 10 toilets close to the living area of the community. Many of the satisfaetory final recommendations involved community participation. The community involvement entailed the education of the community to assume responsibility and address the sanitation challenges. These challenges included the community helping to construct sanitary faeilities, spreading awareness of sanitation, or raising funds to build sanitary facilities. One student (2013886) also proposed that the community pay a minimum cost to use the system. Some other satisfactory responses included enlisting support of various organizations to solve the problems and starting a fund-raising campaign for the community. Two of the final recommendations related to the development of cost effective solutions.

This concludes the analysis of category 2 responses to the sixth question on technological literacy. The analysis of category 3 students' responses follows below.

6.4.6.3. Category Three Students' Responses to Technological Literacy Question Six

Category 3 students' responses had a greater depth than category 1 and 2 students' responses. This depth was revealed in some highly technical responses as illustrated below. Further, unlike the previous two categories of students, a silent or irrelevant or inadequate response to components of question six was rare.

In the component on investigations pursued to resolve the challenges of poor sanitation, the category 3 students presented very intriguing approaches to their investigations. For example, some students wanted to explore the replication of solutions that were applied in similar situations elsewhere. Others were more enterprising in their approach in that they wanted to pursue a combination of geological (soil type and ground stability) and meteorological (weather conditions) surveys together with urban planning strategies to ensure that the system is scalable and adaptable. Cost effectiveness and community participation were pervasive issues.

Many of the investigations included a focus on cost effectiveness, e.g. who would finance the project, can the community afford to pay for a viable sanitation system, and what would be the cost to erect public sanitation structures for communal use.

Community involvement was also a key factor for many of these students. They were interested to know whether the community was willing to assist, and whether they would be able to maintain the system. The knowledge of the settlers about sanitation was also questioned, and most importantly, "what are the needs of the people?"

There were also routine responses, and the most common approach was to determine what facilities were available, what needs to be improved. Others areas of category 3 students' interest included the community's access to and sources of water, the geographical layout of the settlement including the water-table level; available space to erect water facilities; garbage removal; risks of disease; and the impact of a new sanitary system on the community.

The design and planning component provided category 3 students with an opportunity to demonstrate their creative flair and technical insights into the resolution of the problem of poor sanitation in an informal settlement. There were some very informed solutions that proposed laying out the settlement in a grid pattern as is common for residential areas; or that water towers should be placed on high-lying land, and purification plants must be placed away from the settlements. Therefore, the quality of responses in category 3 was superior to those in categories 1 and 2.

The key categories of the remaining responses pertained to the centralization of sanitation facilities, creative strategies of dealing with high costs, community involvement, kinds of sanitation systems, and geological considerations.

In an attempt to centralize the facilities that would be made available to the community, category 3 students proposed "communal sanitization areas." These communal areas consisted of one bathroom/shower/toilet combination for every 5 people, or an ablution block per row of houses. One student insisted that the communal facilities ensure privacy.

The cost challenges were also addressed very creatively through corporate sponsorships, or through government subsidies. Some category 3 students wanted the community to raise their own funds through collecting paper, plastic, glass and soft drink cans for recycling purposes. Other students wanted the people to pay for water and electricity. The cost saving devices were impressive as well, e.g. the use of showers that do not run for more than 10 minutes, and toilets with half flushes for urination and full flushes for defaecation.

Community involvement was another pervasive theme in the design and planning component. The category 3 students were keen to engage the community in the construction of plumbing facilities, maintenance, pick-up and clean-up operations, and in advocacy. With regard to advocacy, the idea was to first raise awareness of hygiene and sanitation issues by making a presentation to the people, using posters, or getting health officials to explain effects of unhygienic living. The establishment of facilities would result in the creation of jobs if the community were willing to be engaged as described above. An important consideration, which did not feature in the categories 1 and 2, was to consider the impact of population growth when designing facilities. The proposed design operated on a fixed ratio of residents to new facilities.

The systems that the students in category 3 proposed included features like easy accessible piping for maintenance, placement of septic tanks, rental portable toilets, and use of water channels. The students were keen to use existing designs for the layout of an efficient sewerage processing plant, also install as many fresh water points as possible. The students also wanted to make sure that regular removal of garbage took place.

The geological focus of the category 3 students came through in responses that suggested an examination of the location of the settlement to establish whether it is in a hole or on a mountain. Other students wanted to create detailed maps of the area, including stand numbers as well as any services already in place.

In the modifying systems to suit contexts component there were some interesting answers which suggested the water purification systems may have to be adapted for low-cost operation, or link the system to the municipal plant. Some students reiterated their design and planning ideas like "construct sewers and plumbing facilities to provide plumbing to every house or construct facilities at every block, similar to the system used at hotels" (2002290) or develop a centrally located water resource. The less interesting responses pertained to establishing portable toilets or pit latrines, and some students offered cautionary advice like do not overstrain the existing system. There were also quite a few inadequate responses and even some restatements of the question.

The sensitivity to the issues of the community component had a mixed set of responses from category 3 students. By and large, students were keen to get the community involved or reach a compromise between the community's and students' views. The few students who were insensitive made some indifferent comments like, "They would just have to accept what is given to them" or encouraged the students just to raise awareness of sanitation system and not to consult with the community. Some of the students offered interesting approaches to solve the win the favour of the community by suggesting that students be persuasive, or that they offer an incentive for the community to implement the new system.

The final recommendations component was essentially a reiteration of some of the key ideas that featured in the four components of question six that preceded this component. Some of the reiterations included portable toilets, durable structures, regular refuse removal, supply of antiseptics for toilets, a central water resource or bathroom/shower/toilet, and low maintenance, low-tech filtration and water management systems. Many of the final recommendations emphasized the critical role of the community to ensure the success of the system as in: "Empower the community to sustain the system by providing them with the "necessary start and skills..." (2015226). Other students focused on cost-effective solutions. Inadequate or no responses were rare.

6.4.6.4. Category Four Students' Responses to Technological Literacy Question Six

Category 4 students' were expected to be as impressive as category 3 students, if not better. They shared the same technological literacy level of 3, but category 4 students had a higher scientific literacy level. However, category 4 students' responses, although similar to those of category 3 students, was not as impressive in technical detail. Surprisingly, there were several inadequate or silent responses.

In the investigations pursued component of question six, category 4 students provided a combination of routine and some impressive responses. The two persistent foci of the investigations pursued component included cost analysis and the involvement of the community. Cost analysis entailed exploring the use of local and inexpensive materials like underwater piping, and identifying available funds for the project. Community involvement entailed eliciting the views of the community and incorporating them into plans. Students also wanted to know if the communities were responsible for any of the problems.

The routine responses included, amongst others, consultations and on-site inspections to identify the existing sources of water and associated health risks, the kind of facilities that already exist, the waste removal systems that exist, the exact number of residents and their requirements of the community. Some students also focused on geological factors like the location of the settlement, the type of soil, and explored piping layout to avoid disturbing houses.

The impressive features presented by category 4 students included the installation of boreholes, tapping into neighbouring water systems, and the concept of septic tanks was elaborated with illustrations. Another interesting feature, which did feature in other categories, was to research solutions proposed in other countries and adapt them accordingly in South Africa.

The design and planning component of question six provided some good insights into sanitation issues. For example, as boreholes were being recommended the possibility of contamination by seepage from toilets did exist, and students therefore recommended that the new toilets or pit latrines be situated approximately 100m away from the water sources and the community. Additionally, the use of septic tanks was emphasized for purification.

Students also offered centralized and decentralized design and planning options to the community. The centralized option necessitated a shared ablution block for every six houses or a cluster living pattern to facilitate use of the common ablution facility. The decentralized option was, of course, the installation of a bathroom and toilet facility in each residence. Students suggested that 20 such facilities be installed for the 100 residents, which translates into a maximum of 5 people per facility. As an interim measure, it was also suggested that temporary sanitation facilities be installed. Other proactive measures entailed exploring the cost of extending the existing sanitation, and checking for the possibility of establishing boreholes.

The community was also involved in the designing and planning, as they were to provide the required labour to establish and maintain the system. For example, when the pit latrines were full, new ones had to be developed by the community. Other community responsibilities entailed refuse removal, laying of pipes for sewers, daily removal of sewerage when applicable and purifying borehole water before using it. The usual cost considerations were mentioned, as in cost-effective underwater piping being installed. More elaborate design and planning measures included the use of architects or engineers to design a suitable system.

The modifying systems to suit contexts component of questions six was unsatisfactorily answered, and had an unusually high number of inadequate or silent responses. There was also a fair amount of repetition with students recommending that the new system be designed to cope with contamination of water due to seepage. Also, the regular removal of sewerage and use of septic tanks was reiterated. The only reasonable responses pertained to supply pipe diameter being smaller at the point of supply and consideration of future upgrades when installing facilities.

The sensitivity to issues and choices of the community of informal settlers component of question six elicited positive feedback from category 4 students. Students were very sympathetic to the community's needs and respected their views. They explored several options to solicit ideas from the community. For example, meetings with the community were proposed, negotiating with the residents to determine the location of the facilities, eliciting feedback from community about their relocation, and seeking final approval from the community about facilities that will be established. Category 4 students also understood that some members of the community might not be familiar with the causes of disease and other effects of poor sanitation and they offered to educate the community.

In the final recommendation component of question six, category 4 students' responses related largely to community endorsement before a final submission to the contractor to the develop system. Many of the students just reiterated some of the ideas that emerged in the previous components of the question. Their terse responses included: an ablution block for every six people, septic tanks for toilets, regular refuse removal, establish bore holes and pit latrines, and the development of cost-effective but efficient systems with educated residents to maintain systems.

6.4.6.5. <u>Summary of Responses to Technological Literacy Question Six</u>

Thus, the responses to the question on SO1 and SO2 in the technology learning area varied considerably across the different categories of students. The completeness and the quality of the responses increased proportionately as we progressed from categories 1 to 3 and category 4 students were satisfactory but not impressive. A brief summary of the responses of each category of students follows.

Category 1 students demonstrated an eagerness to answer the first two components of this question, namely investigations pursued, and design and planning. Thereafter, their interest waned and they provided irrelevant or no responses.

Category 2 students' responses were more refined than category 1 students' responses. Some students exhibited the general pattern of category 1 students because they answered the first two components of the question and simply ignored the remaining three components. In the component on investigations pursued, there was a combination of responses on a continuum from inadequate through to impressive. In the component on design and planning, cost-effectiveness was a pervasive component, and the responses were inadequate, routine, innovative and impressive. The component on modifying systems to suit contexts was generally poorly answered by category 2 students with the exception of the odd, meaningful response. Students in category 2 also poorly answered the component related to sensitivity to the issues and choices in the community of informal settlers. Just under half of the students either did not answer or provided irrelevant answers. The final recommendation component of the question was also poorly answered with more than half the students providing no response and irrelevant or inadequate responses. The remaining students provided a few average and a variety of satisfactory final recommendations.

Category 3 students' responses had a greater depth than category 1 and 2 students' responses. This depth was revealed in some highly technical responses. Further, unlike the previous two categories of students, a silent or irrelevant or inadequate response to components of question six was rare.

In the component on investigations pursued to resolve the challenges of poor sanitation, the category 3 students presented very intriguing approaches to their investigations. Others were more enterprising in their approach in that they wanted to pursue a combination of geological (soil type and ground stability) and meteorological (weather conditions) surveys together with urban planning strategies to ensure that the system is scalable and adaptable. Cost effectiveness and community participation were pervasive issues.

In the design and planning component, there were some very informed solutions. The key categories of the remaining responses pertained to the centralization of sanitation facilities, creative strategies of dealing with high costs, community involvement, kinds of sanitation systems, and geological considerations.

In the modifying systems to suit contexts component there were some interesting answers, but some students reiterated their design and planning ideas, and some less interesting responses like portable toilets. There were also quite a few inadequate responses and even some restatements of the question.

The sensitivity to the issues of the community component had a mixed set of responses from category 3 students. By and large, students were keen to get the community involved or reach a compromise between community's and students' views. The few students who were insensitive made some indifferent comments. Persuasion and the use of incentives were encouraged.

The final recommendations component of category 3 students was essentially a reiteration of some of the key ideas that featured in the four components of question six that preceded this component.

Category 4 students' responses, although similar to those of category 3 students, were not as impressive in technical detail. There were also several inadequate or silent responses. In the investigations pursued component of question six, category 4 students provided a combination of routine and some impressive responses. The two persistent foci of the investigations pursued component included cost analysis and the involvement of the community. The design and planning component of question six provided some good insights into sanitation issues. Students also offered centralized and decentralized design and planning options to the community. The modifying systems to suit contexts component of questions six was unsatisfactorily answered, and had an unusually high number of inadequate or silent responses. There was also a fair amount of repetition. The sensitivity to issues and choices of the community of informal settlers' component of question six elicited positive feedback from category 4 students. Students were very sympathetic to the community's needs and respected their views. They explored several options to solicit ideas from the community. In the final recommendation component of question six, category 4 students' responses related largely to community endorsement before a final submission to the contractor to the develop system. Many of the students just reiterated some of the ideas that emerged in the previous components of the question.

6.5. Conclusion

This chapter examined critical question 3, i.e. what were the levels of technological literacy in the selected cohort of undergraduate science students? The principal focus of this chapter was on the qualitative analysis of the results of the technological literacy test completed by the selected students. This qualitative analysis was preceded by two quantitative precursor components.

After providing, amongst others, a brief review of the linkages between the technological literacy outcomes of C2005 and the six technology related questions that featured in the questionnaire; and confirming the near normal distribution of the data, the true qualitative analysis commenced. The results of the analysis revealed that, as predicted in chapter one, that one way to demonstrate an outcome in technology, is to use open-ended, yet focused, questions. However, an assessment system, which quantifies the responses to these open-ended questions, is not yet in place in South Africa. One of the options, which South Africa may choose from in assessing the qualitative outcomes outlined in C2005, is the SOLO Taxonomy as described in chapter three.

In using the SOLO taxonomy to analyze the six technology related questions, there were two distinct phases. First, assigning a SOLO taxonomy status and number to a response like pre- (1), uni- (2) or multistructural (3), relational (4), or extended abstract (5). The technological literacy scores of the students were confined to the prestructural, unistructural, and multistructural levels with rounded scores of 1, 2 and 3 respectively out of a total of 5. None of the students were able to score at the relational or extended abstract level, which required scores of 4 and 5 respectively out of a total of 5. It is important to note that the technological literacy score of a student in this study represented the ***mean*** score for 11 sub-questions. Therefore, if a student were classified as unistructural, it did not preclude the possibility of that student having some uni- and multistructural responses as well. The technological literacy levels of the students were then combined with their scientific literacy levels and there was considerable overlap. The combined categories (see Table 6.5. p.138) were used to analyze the responses qualitatively.

The qualitative analysis revealed that for each of the six technology related questions, there was a generally a spread of responses from inadequate to superior, and the quality of the responses were generally aligned to the categories of students. For example, the responses to the question on selecting and evaluating products and systems (i.e. describing the technological features of a cell phone) started with category 1 students who were either incorrect, avoided answering the questions, focused on irrelevant information, or provided incoherent responses. Category 2 students' responses were a combination of mediocre and poor responses. Category 3 students offered more refined responses than their counterparts in categories 1 and 2. Category 3 students still provided a list of technological factors but enhanced the list with the use of labels like ergonomics. Category 4 students' responses were similar to those of category 3 students.

One can conclude from this illustrated analysis of the question related to a cell phone, that in order to successfully demonstrate the associated outcome of selecting and evaluating products and systems, there are different levels through which learners must progress. Sure, some learners may be able to automatically qualify at the SOLO taxonomy level of multistructural or even extended abstract level. However, there are other students who will be confined to pre- and unistructural levels when they first encounter the challenges presented in demonstrating an outcome. These students will have to be guided through processes that will elevate their understandings to reach higher SOLO taxonomic levels.

The sad reality is that many educators, education officials and academics are proceeding with the implementation of C2005 without this understanding of how to quantify essentially qualitative outcomes. While Chisholm et al (2000) made several recommendations on the proposed changes to the structure of the curriculum, there was a distinct silence on simplifying the assessment of outcomes as illustrated with the SOLO Taxonomy above. 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 judgements and he proposes the SOLO taxonomy as one system to achieve this outcome. The foregoing analysis confirms that the SOLO taxonomy is a feasible option to pursue when assessing qualitative answers.

Chapter Seven

Synthesis, Recommendations and Conclusion

7.1. Orientation to the Chapter

The foregoing voyage of exploration into the scientific and technological literacy of the cohort of first year physics students and the effects of a traditional school curriculum yielded a sea of data. This chapter crystallizes the principal findings with reference to the critical questions that were pursued in this study, and then discusses each set of findings. Further, the chapter will provide recommendations related to these principal findings, and address limitations of this study by offering suggestions as to how the study could be replicated and/or taken to scale. The novelty of this chapter lies in its integration of elements of the literature reviews, statistical analyses, and revelations of the focus group interviews, which will be used to compare, corroborate and/or contest the principal findings of the foregoing analysis.

7.2. Synthesis of Results Related to Critical Question One

The first critical question had two distinct foci. First, an examination of the nature of the traditional science syllabi and teaching practices that the selected undergraduate physics students experienced at school. Second, a comparison of the traditional science curriculum with transformational OBE in science and technology.

Accordingly, most of the findings related to the first critical question can be separated into two categories. The findings that are informed by empirical data, i.e. findings derived from the questionnaire administered to the students (see Appendix 1), are called essential findings. The other findings, which have a theoretical underpinning, and are derived from the comparison of the traditional and transformational OBE curricula, will be classified as supplementary findings.

The essential findings associated with the nature of the teaching and learning experiences of the students will be presented collectively so as to constitute a direct response to the first critical question. Thereafter, a discussion will follow, which will be informed by supplementary findings that are distilled from the comparison of the traditional and transformational OBE paradigms.

7.2.1 Findings Related to Critical Question One

The five essential findings related to critical question one were:

Finding One:

The teaching methods of students who experienced traditional science curricula at school were largely conventional. Chalk and talk was the most popular method of teaching. The second most popular teaching method was the use of questions and answers.

Finding Two:

Science experiments and group work, were the least popular of the teaching methods.

Finding Three:

The learning experiences of the students were not consistent with traditional teaching methods. The most common learning method amongst the students was more progressive in that it focused on the use of numbers, concepts, and principles to solve problems. The use of concepts and principles to solve problems was the second most popular learning method.

Finding Four:

Although the learning methods experienced most frequently by the students were not a mirror image of the most frequent teaching methods, the influence of traditional teaching practices on learning methods could not be ignored. Many students were still inclined to pursue traditional learning methods like memorization (rote learning) and use numbers exclusively to solve problems.

Finding Five:

There is dependence, at a five and ten percent level, between some of the teaching and learning experiences of the students. The strongest dependence at the five-percent level using the chi-square test statistic is between the science experiments teaching method and relating physics to real life as a learning method.

7.2.2. Discussion of Findings Related to Critical Question One

According to the first essential finding, the most frequent teaching methods experienced by the students resonated strongly with the traditional science curriculum. Chalk and talk was the most frequent kind of teaching experienced by the students. The second most frequent teaching method entailed the use of questions and answers.

Both of the most popular teaching methods are consistent with the supplementary theoretical finding that the learning theory of Behaviourism had a significant influence on the teaching practices of educators. According to the CUMSA Discussion Document (DOE 1992a:30), Natural Sciences "concerns itself with imparting knowledge..." The data implies that chalk and talk, and the use of questions and answers, were the most convenient form of imparting knowledge. Behaviourism, encouraged presenting knowledge "in small, step by step, simple units" (Ornstein & Hunkins 1998:133) like a teacher does when using the chalk and talk teaching method. Behaviourism also encourages observing behaviours to test learning like a teacher does when they solicit answers to test learning. This first essential finding was not surprising because to fulfil the requirements of a curriculum that focused on imparting knowledge necessitated an approach that "...is subject-centred where the teacher is viewed as the authority and the expert in the subject field" (Ornstein & Hunkins 1993:42).

There are striking differences between traditional teaching methods and those proposed within the transformational OBE framework. OBE in South Africa signals a change "from a talk and chalk – rote learning system to being flexible and (adapting) to learner needs and different learning styles and learning preferences" (DOE 1997b:42). In transformational OBE, "...the educators (are) active participants or guides on the side or facilitators of learning, and there is "activity based learning where learners explore ideas and approaches to learning and practice skills" (DOE 1996a:46).

The second essential finding established that science experiments and group work, were the least popular of the teaching methods. The centrality of the teacher was further emphasized in science experiments and group work being the least popular of the teaching methods. Both of these teaching methods are more learner-centred, and the results reveal that they were generally discouraged.

There are two supplementary findings that inform this second essential finding. First, practical work was the stepchild of the traditional science curriculum. There were no deliberate attempts to fully integrate theory and practicals in the traditional curriculum. The examinations for practical work were separated from the theory papers; however, the concepts inherent in the practical work could be examined in the theory papers, as outlined in the Syllabus for Physical Science (DOE 1994). Hence, there was an artificial separation of the theory and practical components of the syllabus. This artificial separation is in direct conflict with the transformational OBE approach, which encourages an "experiential and integrated approach" (Chisholm et al 2000:23) and for learners to "gain skills, knowledge and values" (DOE 1997a:10). Transformational OBE encourages "the setting of tasks that integrate theory and practice, the manual and the mental learning where practicable, and which link the classroom learning to the broader society in which it is located" (DOE 1996a:46).

The other supplementary finding which supports this second essential finding was that the world of science was separate from the world of the students. For the most part, the traditional curriculum ignored the fact that students are sources of subject knowledge, skills and attitudes as group work was the least popular method of teaching. Cooperative and activity based learning contexts were not consistent with the traditional curriculum. The traditional approach suppressed individual expression, and did not see learner contributions as supplementary to the body of knowledge in the syllabus. Also, teachers were not au fait with such a teaching methodology. Hence, it was remarkably unpopular. Textbooks prescribed in a recipe format the 'experimental method,' and provided the answers to the so-called discovery questions immediately after the experiment. These are just a few illustrations of how the traditional curriculum perceived the world of science as separate from the world of the student. On the other hand, transformational OBE explicitly endorses group work and appreciates the students as sources of knowledge, skills and values. More specifically, transformational OBE endorses the learning theory of Constructivism in which learners construct new knowledge using their original ideas.

The third essential finding established that the learning experiences of the students were not consistent with teaching methods. One would expect that because chalk and talk was the most popular teaching method, that there would be a corresponding high frequency for associated learning methods like memorization or the exclusive use of numbers to solve problems. Surprisingly, the most common learning method amongst the students was the use of numbers, concepts, and principles to solve problems. The high frequency of the use of numbers, concepts and principles as a method of learning was not an outlier result; it was consistent with other results. This deduction is based on the fact that the second most popular method of learning was the use of concepts and principles. Hence, it is apparent that this cohort of students was more suited to the conceptual approach to solving problems.

Supplementary findings indicate that the learning methods, which were popular amongst the students, are more consistent with the transformational OBE curriculum. In fact, this essential finding resonates with one of the specific outcomes for the Natural Sciences as outlined in the Discussion Document of C2005, namely: "Demonstrate an understanding of concepts and principles, and acquired knowledge in the Natural Sciences" (DOE 1997a:134). The use of a combination of concepts, principles, and numbers to solve problems is at a higher cognitive order than simply inserting numbers into an equation and then finding the value of the unknown variable. It requires a grasp of concepts and principles, and a skill of relating them to numbers. For example, to understand the concept of kinetic energy goes beyond just memorizing an equation ($1/2mv^2$). It requires an appreciation of the energy changes that occur when the velocity of the object changes, and to be able to operate at an abstract level to understand the principle of conservation of energy because when an object is in free fall it gains kinetic energy while it loses potential energy.

The use of higher order learning methods could also be attributed to the fact that the teaching methods that were experienced by the students were not exclusively traditional. Problem solving, which is a more cognitively challenging approach to teaching, was the third most popular kind of teaching experienced by the students. Problem solving is inconsistent with the traditional science curriculum teaching methodology. All the teachers who taught the traditional science curriculum cannot be painted with the same brush. Some teachers were more learner-centred in their approach and they emphasized problem solving skills and critical thinking. Therefore, the coexistence of such teachers could have led to a high frequency of the higher cognitive order learning methods that entailed the use of numbers, concepts and principles to solve problems.

The fourth essential finding confirms that despite the tendency of the students to favour conceptual approaches to problem solving, traditional learning methods like memorization and the use of numbers exclusively to solve problems were still very popular. In fact, they were almost equivalent to learning methods like relating physics to real life and the use of one's own ideas to understand physics. Therefore, the influence of the traditional curriculum cannot be ignored. The supplementary finding pertaining to the significant effect of Behaviourism on the traditional curriculum applies to this essential finding. Additionally, the underlying educational philosophies of Essentialism and

Perennialism also impacted the learning methods embraced by the students as they underpinned the traditional curriculum. Perennialism is rooted in the acceptance of generally agreed-upon knowledge of the past. Such an approach leaves little opportunity for students to create their own meanings of content, and to use students' ideas as a point of departure when designing a learning session. Essentialism focused on cognitive and intellectual essentials, but encouraged a passivity of students and the centrality of the teacher.

Another supplementary finding pointed to the assessment system of the traditional curriculum encouraging traditional learning methods like memorization and the use of numbers exclusively to solve problems. In any educational setting, the assessment method has a profound influence on the nature of the learning methods pursued. The traditional assessment system was designed to test mastery of knowledge. Two factors adversely affected students' success with such an assessment system. First, the huge volume of information and second, the summative nature of the testing. Students were confronted with a syllabus that was content laden, and in which application of knowledge was not important. Moreover, students were confronted with summative assessments in the form of mid-year and final examinations. This meant that huge volumes of information had to be retained by students to be restated in the examinations. The examinations were also high stakes as they determined progression to the next grade.

In contrast to the traditional curriculum, the shift to OBE requires a formative and summative approach to assessment, as teachers must assess learners' progress continually. Assessment in an OBE system enables both learners and teachers to determine whether learners are achieving the agreed outcomes or not. A variety of strategies are used to measure the process and product of learning, namely, "tests, essays, projects, and portfolios" as outlined in Outcomes-Based Education in South Africa, Background Information for Educators - Draft (DOE 1997b:41). Self or peer assessment may also be administered.

Fifth and finally, the chi-square test statistic and the Pearson Correlation Coefficient confirm that there is dependence at a five and ten percent level between some of the teaching and learning experiences of the students. The strongest dependence at the five-percent level using the chi-square test statistic is between the science experiments teaching method and relating physics to real life as a learning method. There are implications of this finding for the implementation of the transformational OBE. You have to tailor the course offerings so that the teaching method induces the desired learning method. For example, if you wanted students to use numbers, concepts and principles to solve problems, then Table 4.2. states that you should engage Science Experiments and Group work as teaching methodologies. Similarly, for those dependencies that exist at the five and ten percent level, corresponding teaching methods should be applied to achieve a desired learning strategy in students.

This concludes the discussion on essential findings related to critical question one.

7.3. Synthesis of Results Related to Critical Question Two

The first innovation of this study was 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 resonated with the OBE paradigm that is currently in vogue in South Africa. The transformational OBE framework manifests itself explicitly in the second and third critical questions of this study.

The second critical question in this study examined the levels of scientific literacy in the selected cohort of undergraduate science students. The primary source of data for critical question two were twenty multiple-choice questions that were linked to four science themes (Earth & Beyond, Matter & Materials, Life and Living, and Energy and Change) from the Natural Science learning area of C2005. For example, a question that was linked to the theme Energy and Change follows:

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

The twenty questions were part of the all-inclusive questionnaire that was administered to the students. The number of correct responses to these twenty questions determined the scientific literacy category into which a student was placed. The categories of students are outlined in Table 7.1. below.

Ranges of Scores out of 20	Category
Less than or equal to 8	Scientifically Illiterate
9 to 11	Mediocre Scientific Literacy
12 to 15	Good Scientific Literacy
16 to 20	Excellent Scientific Literacy

Table 7.1. The Scientific Literacy Categories of Students

The above scores for scientific literacy were then examined to determine which questions were answered correctly in each of the categories of scientifically literate students. Such an analysis revealed patterns with regard to the nature of questions correctly answered by each of the groups. This was a new dimension in the analysis of the scientific literacy levels of the students. The analysis entailed an examination of the questions with the most, moderate and least number of correct responses by concept, theme, discipline, and an explanation of the patterns that emerged. Additionally, data derived from focus group interviews were used to analyze students' conceptions of scientific literacy. Moreover, biographical data derived from the questionnaire was used to establish which of the teaching and learning methods were the most influential in determining scientific literacy levels, and which factor was the best predictor of scientific literacy. The findings of this analysis are presented below.

7.3.1. Findings Related to Critical Question Two

The findings that are presented below are of two distinct types. Those findings that are a direct response to the second critical question are essential findings. Findings one and two below are essential findings. Those findings that are not a direct response to the second critical question, but do inform the understanding of the scientific literacy levels of the students, are supplementary findings. Findings three to six below are supplementary findings.

For critical question one, the essential findings were derived exclusively from empirical methods; i.e. data generated from the questionnaire yielded the essential findings. The same applies for essential findings related to critical question two. For critical question one, the supplementary findings were derived from a theoretical comparison of the traditional and transformational OBE paradigms. However, the supplementary findings for critical question two are not derived theoretically. Rather, they are derived from a quantitative analysis of data from the questionnaire and qualitative analysis of

Finding Three (Supplementary Finding):

The analysis of the questions that were answered correctly in each of the categories of scientifically literate students (see Table 7.1. p.179) by theme and concept yielded the following preferences for disciplines in science:

Scientific Literacy Level	Most Popular Discipline in Sciences
Scientifically Illiterate	Life Sciences
Mediocre Scientific Literacy	Life Sciences
Good Scientific Literacy	Life and Earth Sciences
Excellent Scientific Literacy	Life, Earth and Physical Sciences

Table 7.4. Most Popular Science Disciplines for Students with Different Scientific Literacy Levels

Finding Four (Supplementary Finding):

The students' conceptions of scientific literacy were consistent with their categorization according to performance on the scientific literacy test.

Finding Five (Supplementary Finding):

Of all the teaching and learning methods, the most influential in determining scientific literacy levels is working in small groups.

Finding Six (Supplementary Finding):

The best predictor of scientific literacy is the former department of education that a student's school was affiliated to.

7.3.2. Discussion of Findings Related to Critical Question Two

The discussion of the scientific literacy levels of the students is guided by the working definition of scientific literacy that was distilled from the literature. Accordingly, scientific literacy 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 (Adapted from Shen 1975, cited in Shamos 1995).

This working definition of scientific literacy is aligned to the scientific literacy test in this study for two principal reasons. First, by and large, the questions in the scientific literacy test attempt to transcend the assessment of scientific vocabulary (the so-called lexical knowledge of science). Some of the scientific literacy questions are aimed at increasing awareness of science-related issues, and the application of that knowledge in real life situations. For example, one question explores the influence of the force of inertia on a passenger travelling in a car when the car changes direction. The second reason why this working definition is chosen for scientific literacy is that the scientific literacy questions in this study are designed to test whether students have the ability to affect public and technological policy. For example, the question on global warming tests if students know whether carbon dioxide gas is responsible for this phenomenon. Thus, if students are in the know, they can affect public and technological policy on reducing the emission of carbon dioxide gas.

The content of twenty multiple-choice questions on scientific literacy resonated with the traditional matric science syllabus. But, the twenty questions were also aligned to C2005 themes in the Natural Sciences as illustrated above. Additionally, science concepts that were receiving attention in the media at the time of development of the questionnaire were also included. The justification for using the old syllabus as a source of content lies in the fact that "content was initially de-emphasized in the new curriculum" (Chisholm et al 2000:22). There was a deliberate silence in the C2005 documents on the nature of the content that must be pursued. This silence was intentional as the specification of content was seen as prescriptive within the OBE paradigm.

The above introduction related to the rationale for a focus on knowledge as per the working definition of scientific literacy, and the sources of content for the twenty questions on scientific literacy, was important as it contextualizes the discussion of the findings which follows.

This study focused on the scientific and technological literacy levels of the first year physics students and the effects of a traditional science curriculum. This discussion pertains to the scientific literacy component of this study. In the discussion of findings that related to critical question one, the teaching experiences of the students were largely traditional, and although the learning methods of the students were more progressive, the effects of traditional teaching experiences could not be ignored. Even though this situation prevailed, the scientific literacy levels of the students were impressive.

The first essential finding for critical question two categorized the students according to their scientific literacy levels. It can be discerned from Table 7.2. that most of the scores for scientific literacy were clustered between 9 and 16 with some of the scores being distributed on the extremes. Thus, the majority of the students (approximately 75,4 %) were of mediocre or good scientific literacy. A limited number (7,6 %) of students were scientifically illiterate, and a reasonable number (17 %) of the students had an excellent scientific literacy. Considering that these students were taught most frequently with the chalk and talk method or through the use of questions and answers, this distribution of scores is good.

One could also argue that the students were products of a traditional curriculum; hence they could have acquired this scientific literacy by rote learning the structured body of knowledge, and the concepts, principles, and ideas that defined traditional science. However, as mentioned in chapter five, the questions on scientific literacy lent themselves largely to the "comprehension and application" which are the second and third levels in Bloom's taxonomy of educational objectives: cognitive domain (Ornstein & Hunkins 1998:280). There were also questions that were more suited to Bloom's first level of educational objectives, namely: knowledge. Even so, these knowledge questions did not entail a recall of facts; they required a sound knowledge of science concepts and principles. Therefore, it was unlikely that the responses to the scientific literacy test were a result of rote learning.

Nonetheless, the high scientific literacy levels of the students were predictable. As mentioned in chapter three, the schools that this cohort of students came from were generally well resourced, and the performance of these students in the matriculation examinations was very impressive. In the six core subjects pursued by these students 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 (see Figure 3.6.

p.64). Based on these two factors, one would expect high levels of scientific literacy amongst this cohort of students with a negligible amount of under performance. This prediction actually held true.

The second essential finding that related to critical question two provided a statistical overview of the scientific literacy levels of the students. According to Table 7.3, the lowest score was 6 with three students achieving this score, and the highest score was 18 with four students achieving this score. Table 7.3. also reveals that there were no absolute scores for scientific literacy, i.e. none of the students achieved a score of 20 out of 20. Also, none of the students scored 0 to 5 which means that those in the scientifically illiterate range (0 to 8 out of 20) were clustered on upper end of the scientifically illiterate continuum.

Moreover, Table 7.3. shows that the mean (average score), median (middle score), and mode (most frequent score) were 12, 13 and 13 respectively. There are two deductions that one can make from these scores. First, the closeness of these scores reflects the near normal distribution of the scientific literacy levels of the students as demonstrated in the frequency plots in chapter five. Second, as all these scores are above 50 percent, this implies that generally the students' scientific literacy levels were above average. In fact, the mean, median and mode were above average by at least 10 percent.

The third finding that related to critical question two was a supplementary finding, and it yielded the preferences for disciplines in science for each category of scientifically literate students (see Table 7.4. p.181). Note that the Natural Science Learning Area consists of the following disciplines: Life Sciences, Earth Sciences, and the Physical Sciences. Table 7.4. is suggestive of an evolution of the students' abilities and understandings of science concepts and application thereof as one progresses from the scientifically illiterate students through to the students with excellent scientific literacy.

According to Table 7.4. the scientifically illiterate students and students with mediocre scientific literacy had a penchant for the simpler Life Science concepts. Students with good scientific literacy had evolved to a higher level with a good grasp of both the simple Life Sciences and the more challenging Earth Sciences. Students with excellent scientific literacy had reached the ultimate level with equivalence in understandings across all three disciplines. The rationale behind this set of findings will be discussed for each group of students.

The students who were classified as scientifically illiterate displayed the following tendencies: the questions that were answered correctly most frequently were from the Life Sciences (e.g. questions on cellular respiration and genetics); the questions with a reasonable number of correct answers reflected a balance between the Life and Physical Sciences; the questions with the least correct answers pertained to the Earth and Physical Sciences. Additionally, the Earth Science questions were poorly answered. Therefore, one can infer that the order of popularity of disciplines for the scientifically illiterate students decreases in the following sequence: Life Sciences, Physical Sciences, and Earth Sciences.

The students who were classified as having a mediocre scientifically literacy displayed the following tendencies: the questions with the most frequently correct answers suggested an affinity for both the Life and Physical Sciences; the questions with a moderate number of correct answers also suggests an affinity for both the Life and Physical Sciences. However, the least correctly answered questions pertained to the Earth and Physical Sciences. Additionally, the Earth Sciences were not as popular as the Life Sciences (see Figure 5.4. p.123). Once again, the Life Sciences emerged as the most popular of the disciplines.

With regard to the type of questions that were most popular amongst students with a good scientific literacy, one could assume that there was no preference as there was almost a similar kind of scoring for Earth Sciences, Physical Sciences and Life Sciences. This equivalence was suggested by the almost linear distribution of high scores across a combination of disciplines. However, with the low scoring variables 5 (seasonal change), 7 (density), 9 (vector sum of forces), 19 (conduction) and 20 (colour of light), there was an overall weakness related to the Physical Sciences. Variables 7, 9, 19, and 20 were part of the Physical sciences, and the variable 7 part of the Earth Sciences. Therefore, one can conclude that the students with a good seientific literacy were more favourably disposed to questions on the Life and the Earth Sciences. Interestingly, there was a distinct shift from the first two groups (scientifically illiterate and those with mediocre scientific literacy) who were more favourably disposed to the Life Sciences.

For students with excellent scientific literacy, the consistency in the distribution of correct responses, is suggestive of a uniform understanding of science concepts, and the application thereof, across the domain of science, i.e. these students had almost equal abilities and understandings in the Natural, Physical, and Earth Sciences. This equivalence in knowledge is manifested by equivalence in scores. The lowest scoring variables for students with excellent scientific literacy were 9 (vector sum of forces) and 19 (conduction), with an average performance on variable 20 (colour of light). As variables 9 and 19 are essentially Physical Science questions, one is inclined to believe that there is a weakness in this group of students in the Physical Sciences. However, their almost perfect scoring for other Physical Science questions, as expressed in the linear distribution of correct responses in Figure 5.7, eclipses their poor performance on these two questions. Thus, the core distillation from the above analysis of the students with excellent scientific literacy is that there is equivalence in the abilities and understandings of these students in all three disciplines, namely, the Physical, Life and Earth Sciences.

What is clearly discernible from the above analysis of scientific literacy levels of a cohort of students is that there will always be a variety of abilities and understandings of scientific phenomena within any cohort of students. This variety in abilities and understandings may be due to variations in teaching, to curriculum content, to student interests, or to a host of other reasons. In the above analysis, it is fairly obvious that the variety is due, in part, to preference or popularity of different disciplines in the Natural Sciences. This differentiation of students by discipline and level of scientific literacy could influence pedagogy and curriculum content in an attempt to improve the scientific abilities and understanding of the selected cohort of students.

The fourth finding that related to critical question two was a supplementary finding, and it pertained to the fact that the students' conceptions of scientific literacy were consistent with their categorization according to performance on the scientific literacy test. The fourth finding is derived directly from the focus group interviews that were administered to homogenous groups of students; i.e. students with similar scientific and technological literacy levels were grouped together. The analysis of the focus group interviews is presented in Appendix 3. The fourth finding corroborated the categorization of students based on their scientific literacy levels. Students in each of these categories offered conceptions of scientific literacy which were consistent with their categorization.

The students who were scientifically illiterate provided acceptable definitions of scientific literacy: "(It) is the understanding of science and its application on a daily basis." However, the shallowness of their understanding of scientific literacy was revealed in responses to a question that enquired how they would test if a person were scientifically literate. Their responses were similar to a conception of scientific literacy known as cultural literacy, advocated by Hirsch (1987, cited in Zuzovsky 1997). He defined the concept as a grasp of basic information needed to thrive in the modern world, something that was then translated into possession of a lexicon of scientific terms.

The scientifically illiterate students' shallow responses related to testing for scientific literacy included: "The way he looks at things and if the person has an enquiring mind" or "By asking...how does it come about to rain?" These students also provided inadequate responses to the question that enquired as to how they use scientific principles in their everyday lives. Their responses included: "Putting a plug into a socket to use electricity. Switching a light on/off." Such responses did not even include an explanation of the scientific concepts and principles at play.

The students with a mediocre scientific literacy provided a set of responses to the concept scientific literacy that were largely related to the lexicon of terms associated with science. There was a specific focus on "understanding of the jargon" or understanding scientific terms and language. Only one response mentioned the application of knowledge, experimentation and observation in real life situations. Their responses on lexical knowledge were also similar to the conception of scientific literacy known as cultural literacy, which was described above.

With regard to the nature of testing for scientific literacy proposed by students with a mediocre scientific literacy, the same kind of lexical thinking prevailed where students wanted to enquire whether or not scientific meanings were understood or do people have "the basic understanding about science". Some responses were tangential like: "Take their lifestyle into consideration – what do they do, read – how do they interpret things in life." One response was quite realistic: "If the person is able to figure out any problem without a solution by himself using his common sense e.g. throwing grass in the air to determine the direction of the wind."

As for the application of science in everyday life, the responses provided by students with a mediocre scientific literacy were rather disappointing as students simply listed examples without elaborating on scientific principles e.g. use of electrical appliances, computers and the Internet. One group of students did attempt to elaborate by stating that a focal point is created when taking photographs.

The students with a good scientific literacy offered responses that combined the foci of the two foregoing groups of students. They offered definitions that combined "the knowledge and understanding of scientific terminologies and theories and the application thereof " or the application of mathematical principles to the real world, towards benefit of mankind. Their conception of science seems to fit best with Shen's (1975, cited in Shamos 1995) practical scientific literacy concept which included the kind of scientific and technical knowledge that can immediately be put to use to help to solve practical problems. They also offered interesting responses as to how they would test for scientific literacy including: "If they can help with your physics homework." Others wanted scientifically literate people to know basic scientific knowledge, and have conversations about science.

As for the use of science in their everyday lives, some students were rather arrogant and stated that "Most principles are instinctive (and) in our subconscious (sic). We don't feel we actually benefit from our studies in physics..." Others listed the example of Crossing a road – you judge the speed and distance, time, of the car approaching, if you'll be able to cross safely.

The fifth finding that related to critical question two was also a supplementary finding, and it pertained to the fact that of all the teaching and learning methods, the most influential in determining scientific literacy levels is working in small groups. An analysis of variance test was administered to establish which of the teaching and learning methods were mostly influential on the scientific literacy levels of the students. At the 10 percent significance, working in small groups emerged as the most influential factor on scientific literacy level. Note that according to chapter three, working in small groups was the least popular of all methods of teaching. 7 % of the students declared that they always used group work as a method of teaching, 17 % experienced it most times, 51 % a few times and 24 % were never exposed to this kind of teaching. Interestingly, the OBE paradigm emphasizes working in small groups as a teaching method and according to this study that should improve the quality of scientific literacy levels.

The sixth finding that related to critical question two was also a supplementary finding, and it pertained to the former department of education that a student's school was affiliated to. This was the best predictor of scientific literacy. A multiple analysis of variance (MANOVA) test was administered to establish which of the following contextual factors was the best predictor of scientific literacy:

a) the first language of the student,
b) the location of school,
c) the former department that the learner's school was affiliated to,
d) the number of learners in the matric science class,
e) the medium of instruction in the matric science class, and
f) the performance of the student in matric.

The MANOVA proved that performance in matric and number of learners in the matric science class had a partial influence on the scientific literacy level at a 10 percent significance level. However, the only factor which influences the scientific literacy level at a 5 percent significance level was the former department that the learner's school was affiliated to. Hence, it was the best predictor of scientific literacy levels. Scheffe's pair wise comparison was used to determine which categories of former departments differ. The pair wise comparison revealed that comparisons were significant between groups 5 (House of Assembly-HOA) and 4 (Department of Education and Culture), 5 (HOA) and 3 (House of Representatives), 6 (Other – Mostly Private Schools) and 3 (HOR), 5 (HOA) and 1 (Department of Education and Training).

This concludes the discussion related to findings associated with critical question two and the focus now shifts to critical question three.

7.4. Synthesis of Results Related to Critical Question Three

The second innovation in this study was the use of the Strategic Objectives Learning Outcomes (SOLO) Taxonomy to arrive at qualitative judgments about responses to questions that tested the technological literacy levels of the students. These qualitative judgements were then quantified using the SOLO taxonomy categories.

The third critical question in this study focused on the levels of technological literacy in the selected cohort of undergraduate physics students. To determine the levels of technological literacy of the students, six open-ended questions were administered to the students as part of the all-inclusive questionnaire. The six questions were based on each of the specific outcomes for technology as envisaged in C2005. Some of these questions consisted of sub-questions. A total of eleven sub-questions on technological literacy corresponded to eleven variables. Each student scored between 1 and 5 points for each of the eleven variables. For example, if a student's response was incorrect, inadequate, or a restatement of the question then that response was coded as prestructural according to the SOLO taxonomy and given a score of 1. Similarly, unistructural responses, which provided one correct response to the question, were scored 2. Multistructural responses were scored 3 as they included many correct aspects of the work but did not integrate them together. In relational responses, which were scored 4, the learner integrated the parts with each other so that the whole had a coherent structure and meaning. Extended abstract responses were scored 5 as the learner focused on more abstract features representing a higher mode of operation.

For each student, the mean of these 11 scores was calculated, and the students were classified 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

(X represents the mean of the scores for the 11 variables, and each of the above classifications is consistent with the SOLO Taxonomy as described in chapter three.)

The categorization of students using prestructural, unistructural, and multistructural labels led to the identification of the students in each of these groups. The three groups of students' scores were compared with their scientific literacy scores. For example, to what extent were students who were scientifically illiterate also exhibiting a prestructural technological literacy? Similarly, mediocre scientific literacy was combined with unistructural technological literacy, good scientific literacy was combined with multistructural technological literacy, and excellent scientific literacy was also combined with multistructural technological literacy because there were no students with relational technological literacy or with extended abstract technological literacy. As there was significant overlap between these two sets of scores, the combined categories were used to perform a qualitative analysis of the six questions on technological literacy. For all six questions on technological literacy, the responses of each category of students were dissected to develop a portrait of the patterns and qualitative differences in the responses of the different combined categories of students.

The foregoing discussion was provided to orient the reader to the process that led to the major findings associated with critical question three.

7.4.1. Findings Related to Critical Question Three

The findings that are presented below are of two distinct types. Those findings that are a direct response to the third critical question are essential findings. Findings one and two below are essential findings. Those findings that are not a direct response to the third critical question, but do inform the understanding of the technological literacy levels of the students, are supplementary findings. Findings three to eight below are supplementary findings.

For critical question one and two, the essential findings were derived exclusively from empirical methods, i.e. data generated from the questionnaire yielded the essential findings. The same applies for essential findings related to critical question three. For critical question two, the supplementary findings derived from a quantitative analysis of data from the questionnaire and qualitative analysis of student responses. The same applies to the supplementary findings for critical question three. Once again, the supplementary findings combine qualitative and quantitative research methods.

Finding One (Essential Finding):

The distribution of students per technological literacy score were as follows:

Technological Literacy Score	Frequency	Percent
1	22	12.9
2	107	62.6
3	42	24.5
	N = 171	100

Table 7.5. The Distribution of Students Per Technological Literacy Score

Finding Two (Essential Finding):

The statistical overview of technological literacy levels of the students yielded the following results:

LOWEST SCORE		HIGHEST SCORE		MEAN	MEDIAN	MODE
Value	Frequency	Value	Frequency			
1.18	7	3.45	2	2.13	2.09	2.18

Table 7.6. Statistical Overview of Technological Literacy Levels of the Students

Finding Three (Supplementary Finding):

There was considerable overlap between the corresponding scientific and technological literacy levels of the students as revealed in Table 7.7. below.

Category	Scientific Literacy Level	Technological Literacy Level	Number of Students
1	Illiterate	Prestructural	5
2	Mediocre	Unistructural	32
3	Good	Multistructural	20
4	Excellent	Multistructural	14
			N =71

Table 7.7. Combined Scientific and Technology Literacy Levels of Students

For each of the combined categories, the responses to all six questions on technological literacy were analyzed qualitatively. This qualitative analysis generated finding four.

Finding Four (Supplementary Finding):

For all six questions, the characteristics associated with each SOLO Taxonomy level were generally mirrored by the corresponding category of students. Thus, confirming that the SOLO Taxonomy is a reliable assessment method of quantifying qualitative responses and using them as a baseline for improvement.

Finding Five (Supplementary Finding):

The students' conceptions of technological literacy were consistent with their categorization as outlined in Table 7.7. Their definitions were confined to interpretations of technological literacy that placed emphasis on conceptual material and technological skill.

Finding Six (Supplementary Finding):

Cooperative learning environments did have a significant effect on the quality of responses to technological literacy questions.

Finding Seven (Supplementary Finding):

There is no relationship between the teaching and learning methods experienced by the students and their technological literacy levels.

Finding Eight (Supplementary Finding):

The first language of a student is the best predictor of technological literacy.

7.4.2. Discussion of Findings Related to Critical Question Three

There is a fundamental difference in the examination of scientific and technological literacy levels of students in this study. Physical Science, Biology, and General Science were subjects that were offered at schools and as such each of them had a structured domain of scientific knowledge. On the other hand, technology has never been successfully mainstreamed in South Africa. A structured domain of knowledge associated with technology has not been defined in South Africa. Therefore, while it is possible to measure scientific literacy because students had exposure to science (Physical, Biological and General Science) education, it is not possible to do the same for technological literacy, as the students were not exposed to technology education. If anything, technology was an afterthought, especially in light of the central focus of the content that even eclipsed practical work. Therefore it is the firm belief of the author that this study does not measure technological literacy, but rather it measures intuitive technological literacy. This is a novel concept that emerged during this study.

Regardless of the status of technology in the traditional science curriculum, the technological literacy levels of the students were acceptable. The first finding of this study, which was an essential finding and therefore a direct response to the third critical question, related to the distribution of students per technological literacy score. The rounded technological literacy scores were from one to three. These rounded technological literacy scores were actually the rounded means of eleven variables related to technological literacy. It is imperative to understand that if a student had a rounded technological literacy score of 2 that this did not mean that s/he scored 2 for all the variables. Indeed, a student with a rounded technological literacy of 2 could have scored 1, 3, 4, or even 5 for some of the eleven variables. Nonetheless, the distribution of students per rounded technological literacy score is reasonable.

A small proportion of the students was in the prestructural category (12.9 %) which implied that on the whole their responses were inadequate, irrelevant or simply a restatement of the question. Most of the students (62.6 %) were in the unistructural technological literacy score. A fair proportion of students (24,5 %) was in the multistructural technological literacy score. Because there were no rounded technological literacy scores in the relational and extended abstract categories of 4 and 5 respectively, it does not mean that there were no individual scores of 4 and 5 for any of the variables. There were indeed technological literacy scores of 4 and 5 for some of the variables but the rounded mean of the eleven variables (rounded technological literacy level) never exceeded 3.

The second finding that related to critical question three, was also an essential finding and it provided a statistical overview of the technological literacy levels of the students. There are three important features of the statistical overview which distinguish technological literacy scores from the scientific literacy scores. First, the range of scores was much smaller for technological literacy as compared to scientific literacy scores. The technological scores ranged from 1.18 through to 3.45 out of a maximum of 5. The scientific literacy scores ranged from 6 to 18. Second, the technological literacy scores were not whole or natural numbers as they represented the mean score for eleven questions on technological literacy. Third, the corresponding mean, median and mode for technological literacy were much smaller and not natural numbers.

Table 7.6. shows that the mean (average score), median (middle score), and mode (most frequent score) were 2.13, 2.09 and 2.18 respectively. There are two deductions that one can make from these scores. First, the closeness of these scores reflects the near normal distribution of the technological literacy levels of the students as demonstrated in the frequency plots in chapter five. Second, as all these scores are close to 2, this implies that the technological literacy levels of the students were largely at the unistructural level of the SOLO Taxonomy.

The third finding that was related to critical question three, was a supplementary finding, and it showed that there was a high level of overlap between the technological and scientific literacy scores. 42 % of the students had corresponding scientific and technological literacy levels as revealed in Table 7.7. What this implies is that one can predict a student's technological literacy with 42 percent confidence if the scientific literacy level is known and vice versa. The level of confidence with which such a prediction can be made is high considering that the scientific levels were informed by a structured domain of knowledge and a set of teaching experiences while the technological literacy levels are based largely on intuition as described above. The combination of corresponding scientific and technological literacy levels of the students was the basis of categorization of students for the qualitative analysis of responses to the six open-ended technological literacy questions.

The fourth finding that related to critical question three, also a supplementary finding, confirmed that for all six questions, the characteristics associated with each SOLO Taxonomy level were generally mirrored by the corresponding category of students. Thus, confirming that SOLO Taxonomy is a reliable assessment method of quantifying qualitative responses and using them as a baseline for improvement.

The qualitative analysis revealed that for each of the six technology related questions, there was generally a spread of responses from inadequate to superior, and the quality of the responses were generally aligned to the categories of students. For example, consider the responses to the question on selecting and evaluating products and systems, which required students to describe the technological features of a cell phone. The responses progressed from category 1 students who were either incorrect, avoided answering the questions, focused on irrelevant information, or incoherent; to category 2 students' responses which were a combination of mediocre and poor responses. Mediocre responses included a list of technological factors like good reception and network coverage but did not attempt to integrate the list of factors and bring any coherence to the response. Lower order responses were commercial in nature or contained irrelevant information. Category 3 offered more refined responses than their counterparts in categories 1 and 2. Category 3 students still provided a list of technological factors but enhanced the list with the use of labels like ergonomics. Category 4 students' responses were similar to those of category 3 students.

One can conclude from this illustrated analysis of the question related to a cell phone, that in order to successfully demonstrate the associated outcome of selecting and evaluating products and systems, there are different levels through which learners must progress. Sure, some learners may be able to automatically qualify at the SOLO taxonomy level of multistructural or even extended abstract level. However, there are other students who will be confined to pre- and unistructural levels when they first encounter the challenges presented in demonstrating an outcome. These students will have to be guided through processes that will elevate their understandings to reach higher SOLO Taxonomic levels.

The fifth finding that related to critical question three, was a supplementary finding, and it stated that the students' conceptions of technological literacy were consistent with their categorization as outlined in Table 7.7. Their definitions were confined to interpretations of technological literacy that placed emphasis on conceptual material and technological skill. This finding was informed by the analysis of responses provided by students during the focus group interviews (see Appendices 2 and 3 for the focus group schedule and analysis respectively).

The literature showed the evolution of the concept of technological literacy from an emphasis on conceptual material; to an emphasis on technological skills; and finally into a multidimensional concept which included applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions.

Category one students' definitions of technological literacy were more inclined towards the first phase in the evolution of the concept as there was an emphasis on conceptual material. The emphasis on conceptual material was evident in definitions like: "It's the understanding of technology like electricity and its understanding by the ordinary people…" There was also a focus technological skills, albeit less conspicuous in the definitions provided by category one students, but more so in the tests for technological literacy proposed by the same students. The emphasis on technological skills was displayed in recommendations of technological literacy tests like: "If a person is exposed to technological appliances and knows how to use them in a daily basis."

Category two students were almost exclusively focused on technological skills. Their responses related largely to the use technological devices in everyday life and being computer literate. For example, one group of students stated that technological literacy meant to "be able to use and feel comfortable with technological equipment and able to adapt to advancements thereof". The ways in which these students in category two proposed to test the technological literacy of the students was also focused on technological skills. There were also some references to conceptual material where students defined technological literacy as a "basic understanding of the jargon".

Category three students had an equivalent focus on conceptual material and technological skills. The focus on conceptual material was displayed in comments like: "The awareness of Technological advances in the fields of mechanics and electronic advance (sic), and the ability to use, apply and improve on these theories." The focus on technological skills was evident in tests for technological literacy, which were about operating modern appliances like computers and cell phones.

There was a silence in all these categories of students on the multidimensional concept to technological literacy which included applications of technology in new situations, an appreciation of societal issues and values, and the use of research skills to arrive at technological solutions. This silence was expected of this group of students whose technological literacy levels were mediocre. As one progresses with technological literacy, it is possible for someone who attain the highest level where s/he 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).

The sixth finding that related to the third critical question was a supplementary finding and it concluded that cooperative learning environments improved the quality of the responses provided by each category of students. This finding was informed by the analysis of responses provided by students during the focus group interviews (see Appendices 2 and 3 for the focus group schedule and analysis respectively). One example related to the technological literacy question on whether the drug AZT should be made available to students, will be used to illustrate this finding.

When a questionnaire was administered individually, category 1 students' responses were inadequate with students either not responding or admitting to having no understanding of the drug AZT. In the focus group interviews, category 1 students provided very coherent and correct responses to the questions. For example, "Yes, it must be available in order to lower the rate of babies born with HIV virus" thus showing clear evidence of understanding of the inhibition of the mother to child transmission by the drug. This was a significant improvement to the individual responses of the same students.

When the questionnaire was administered individually, category 2 students' responses were of three types: 1) a combination of informed answers which reflected some understanding of the drug and its use; 2) responses which were purely speculative or in which students admitted having no clue about what the drug; and 3) responses which defended the government's standpoint on not making the drug available to pregnant women. In the focus group interviews, once again, students provided very coherent responses to the question. One group stated explicitly, "it lowers the risk of their unborn child contracting AIDS," thus demonstrating clearly that the understanding of mother to child transmission of the virus and the effect of the drug. Once again, there was a significant improvement to the individual responses of the same students.

In the questionnaire, category 3 students were generally able to provide coherent responses to the question on whether AZT should be made available to pregnant women. In the focus group interviews, there was no doubt that the students knew what the drug was used for, but they went a step further. The students took the discussion to new heights by focusing on societal and political issues. This is the highest level of technological literacy and is supported in the working definition of technology provided above. In terms of societal issues, the students enquired about the increase in the number of orphans, as the mother's death would only be prolonged. They also discussed the ongoing debate in South Africa as to whether poverty causes AIDS and contested that viewpoint. Thus, they were truly exhibiting technological literacy as envisaged by the working definition of technological literacy in this study. They were analyzing the pros and cons of any technological development, to examine its potential benefits (and demerits), and exploring the underlying political and social forces. Interestingly, cooperative learning was not a focus of the traditional curriculum. But it is in the new OBE approach to science and technology. What this finding suggests is that we have the potential to improve the quality of technological literacy of the students if we allow them to collaborate on learning activities.

The seventh finding that related to critical question three, also a supplementary finding, confirmed that there is no relationship between the teaching and learning methods experienced by the students and their technological literacy levels. An analysis of variance test was administered to establish which of the teaching and learning methods were mostly influential on the technological literacy levels of the students. At the 5 and 10 percent significance level none of the teaching and learning methods had an influence on the technological literacy levels of the students. This finding is not surprising in the least as it was mentioned above that technology, like practical work, was the stepchild of the traditional science curriculum. Therefore, neither the teaching methods nor the learning methods were geared towards technology. The learning related to technology was either as a result of limited discussions in the traditional curriculum on the application of scientific knowledge or because of personal interest displayed by the students in technological advancements. The interesting part of this finding lies in the challenge that it presents for the success of technology in the OBE curriculum, as it does not point to a specific learning or teaching method that can be pursued to enable technological literacy.

Finally, the eight finding related to the third critical question, yet another supplementary finding, showed that the first language of a student is the best predictor of technological literacy. A multiple analysis of variance (MANOVA) test was administered to establish which of the following contextual factors was the best predictor of technological literacy:

a) the first language of the student,
b) the location of school,
c) the former department that the learner's school was affiliated to,
d) the number of learners in the matric science class,
e) the medium of instruction in the matric science class, and
f) the performance of the student in matric.

The MANOVA proved that the only factor that influenced the technological literacy level at a 5 percent significance level was the first language of a student. Hence, it was the best predictor of scientific literacy levels. None of the remaining contextual factors were influential on technological literacy levels, even at a 10 percent significance level. Scheffe's pair wise comparison was used to determine which categories of first languages differ. The pair wise comparison revealed that there were no significant differences between the different language groups.

As mentioned in chapter three, the first language of the students was one of the two variables in this study that were used as proxy indicators to determine the racial distribution of the sample. The first language of a student was defined in the questionnaire as the language that was used most often by the student. 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.

This concludes the discussion related to the findings associated with critical question three. The focus now shifts to recommendations that emerged in the course of his study.

7.5. Recommendations

There are two sets of recommendations offered below. First, a set of recommendations related to selected findings of the study. Second, a set of recommendations that address the limitations of this study.

7.5.1. Recommendations related to Selected Findings of this Study

There are six principal recommendations. Each of these recommendations are linked to one of more selected findings related to the three critical questions in this study.

It is apparent from the first and second essential findings of critical question one that behaviourist approaches to teaching still fingerprint the educational system in South Africa. This was evident in the high frequencies with which chalk and talk and the use of questions and answers featured as science teaching methods at Grade 12 level. The first recommendation is that deliberate attempts be made, through legislation, to facilitate the execution of more progressive science teaching methodologies in grades 10 to 12. These progressive teaching methods are currently being explored in the lower grades in South African schools but the system cannot afford to delay the same in higher grades because of the sequential manner in which OBE is being introduced into the schooling system. This research (essential finding five of critical question one) also points to specific teaching methodologies that need to be engaged in the higher grades. For example, the strongest dependence between teaching and learning methods at the five percent significance level using the chi-square test statistic was between the science experiments teaching method and relating physics to real life as a learning method. Hence, the mainstreaming of science experiments would enhance the quality of the learning methods embraced by the students as they would begin to relate physics to real life situations. Note that according to essential finding three of critical question one, practical work (science experiments) was the stepchild of the traditional science curriculum. Other teaching methods that this study proposes be focused on in the higher grades, using the Pearson correlation coefficient test results, include working in small groups as it was closely related to the learning method of using numbers, concepts and principles. Further, working in small groups proved to be the most influential learning method on scientific literacy levels of the students according to supplementary finding five for critical question two. Moreover, supplementary finding six of critical question three showed that cooperative learning environments did have a significant effect on the quality of responses to technological literacy questions.

The second recommendation pertains to uniting the world of the student with the world of science. As mentioned above, the fourth essential finding of critical question one demonstrated how the experiences of the students were ignored in the development of an understanding of science knowledge. Evidence of this finding lay in the fact that the use of student-centred science experiments were unpopular, and group work was the least popular method of teaching. But how does one go about uniting the world of a content-laden syllabus with a high stakes matric (Grade 12) examination, that is also content-oriented, with the variety of ideas with which students arrive at school with. The justification for doing so is even more important than describing the how part because if the learner does not make meaning of the knowledge presented at school by linking it to his own set of ideas, the knowledge will never be assimilated. Nonetheless, I will still provide a process option to blend the world of the student with the world of science. It is clear from the ongoing debates about the implementation of C2005 in the lower grades that there was an overwhelming shift to process and a de-emphasis on content. To successfully link the world of the student with the world of science in the higher grades we need to straddle both content and process equally. The science syllabus for the higher grades in science has remained static for the last fifteen years as discussed in chapter four. The syllabus needs to be redefined in terms of content and processes that incorporate the outcomes related to science and technology as envisaged in C2005. Such an approach must transcend what is available in the Discussion Document of C2005 (DOE 1997a). The essence of the approach would be to identify content, knowledge and skills which are fundamental to learn science, identify ways in which information can be elicited from learners to engage with that knowledge, and then facilitate the exchange of ideas between these two worlds of science and the student.

The third recommendation relates to the first and second essential findings of critical question two, which highlighted the impressive levels of scientific literacy of the students who experienced a traditional science curriculum. Indeed, we need to maintain and improve on these levels of scientific literacy. Very often when there is a change in the government; there is a tendency to replace all that existed under the predecessor. The same holds true for C2005, which has attempted to displace every trace of the traditional system. However, this might not necessarily be the best option in light of the findings, which show impressive scientific literacy levels for products of the traditional curriculum.

Hence, an eclectic approach is recommended which embraces the merits of both the traditional and the new OBE approach. This might entail the use of the traditional science curriculum to prioritize the content of science syllabus and the use of the C2005 framework to identify the best processes associated with facilitating an exchange between students' experiences and the content. This melting pot of the traditional and C2005 approaches could improve on the scientific literacy levels.

The fourth recommendation pertains to the preferences of students for the different disciplines (Life, Earth, and Physical Sciences) in the Natural Science learning area. It is evident from supplementary finding three related to critical question two, that students with lower scientific literacy levels prefer the Life and Earth Sciences, while students with higher scientific literacy levels demonstrate an equivalence in understanding across all three disciplines. As mentioned in the discussion, this differentiation of students by discipline and level of scientific literacy could influence pedagogy and curriculum content in an attempt to improve the scientific abilities and understanding of the selected cohort of students. The fourth recommendation echoes the C2005 approach, which eliminates the barriers that exist between these three disciplines. C2005 insists on a co-existence of the three disciplines regardless of the theme (e.g. Life and Living) of Natural Science that is being pursued. The three disciplines are inextricably linked regardless of the theme that is being pursued. For example, by showing the linkages associated with the three disciplines, and using practical demonstrations to show how we engage the Physical Science concepts in our daily lives, students will understand that the Physical Sciences is no different than the Life and Earth Sciences. Of course, more time would be apportioned to the thematic approach.

The fifth recommendation is related to essential findings one and two of the third critical question which highlight acceptable, but not particularly striking, levels of technological literacy of the students. As mentioned in chapter three, technology education does not have a structured body of knowledge, of organizing concepts, of underlying and fundamental principles, ideas that define an academic discipline. Therefore, it follows that there is no valid way of determining curriculum content. Hence, my theory is that this study did not measure technological literacy in the true sense. What was measured in this study is 'intuitive technological literacy' as the students did not take the subject at school level, and if they had exposure to technology education, it had no structured domain of knowledge.

It is therefore recommended that South Africa define a structured body of knowledge with organizing concepts, underlying and fundamental principles, and ideas for technology. Technology has never been successfully mainstreamed in South Africa. There have been attempts at this effort in South Africa as discussed in chapter two. For example, the T2005 Project commenced with a focus on a National Curriculum Framework for Technology Education but ended up focusing on the integration of technology into the life-skills curriculum, which sidelined technology. If the syllabus for technology can be defined, it will help to overcome the confusion that currently prevails about whether technology is deserving of a learning area status.

The sixth and final recommendation is the most important in terms of the future of qualitative assessment practices in South Africa. Supplementary finding four of critical question three revealed that for all six questions on technological literacy, the characteristics associated with each SOLO Taxonomy level were generally mirrored by the corresponding category of students. Thus, confirming that SOLO Taxonomy is a reliable assessment method of quantifying qualitative responses and using them as a baseline for improvement. According to the Centre for Education Policy Development submission to the Review Committee on C2005, C2005 lacks of grade-based benchmarks against which to assess learner performance. Part of the reason for the latter is because "the assessment criteria are broadly stated and do not themselves provide sufficient details of exactly what and how much learning marks an acceptable level of achievement of the outcome" according to the Discussion Document of C2005 (DOE 1997a:12).

The recommendation then is that we begin to explore the implications of the use of the SOLO taxonomy at scale in South Africa. Many educators, education officials and academics are proceeding with the implementation of C2005 without this understanding of how to quantify essentially qualitative outcomes. While Chisholm et al (2000) made several recommendations on the proposed changes to the structure of the curriculum, there was a distinct silence on simplifying the assessment of outcomes as illustrated with the SOLO Taxonomy above. The SOLO Taxonomy will provide South Africa with a simple, yet systematic, method of facilitating learner performance reviews and learner progression.

7.5.2. Recommendations related to the Limitations of this Study

This study was conducted independently by the author, and as such there were human resource limitations. Thus, the scope and depth of the study were informed by these limitations. Consequently, for the sake of convenience, the focus of this study was confined to a single cohort of physics students at one institution, namely the University of Pretoria, who had experienced a traditional science curriculum at school. Indeed, this limits the extent to which the findings of this study can be extrapolated to all students who experienced traditional science curricula at school. Therefore, if this study were to be replicated or taken to scale, it is recommended that the target and sample populations are of greater magnitude and that they be selected from many institutions.

The second limitation of this study pertains to the nature of the questions on scientific and technological literacy. The author and the supervisor made concerted efforts to develop a collection of questions and review them objectively before the final selection was made. It was also the first time that scientific and technological literacy questions were being developed for research purposes within the framework of OBE. The questions were linked directly to the four themes in the Natural Science learning area and they resonated with the specific outcomes of Natural Sciences and Technology.

There is a universe of questions that can be developed for the purpose of testing scientific and technological literacy. Our collection of questions was limited in number and shaped by our own subjective biases. We did validate the questionnaire by piloting it with Technology Education students and incorporated their contributions in the final version of the questionnaire. Nonetheless, it is possible, with more resources and with additional time, to develop a data bank of questions, which are more objective. These questions can then be used to determine with greater accuracy the scientific and technological literacy levels of the students; i.e. the results will be more reliable.

The nature of some of the questions that were used in the test on scientific literacy can definitely be improved:

Question four pertained to seasonal change, and the author believed that this phenomenon was best explained by the tilting of the earth. However, one could also combine the latter with the alternative that related to the position of the earth relative to the sun. This combination could be correct because the word 'position' is an ambiguous one. The word position could have three meanings:

a) it can be interpreted to mean position of the earth within the solar system but that is not explicit;
b) it could mean position of the earth during the revolution of the earth but that is not explicit; and
c) it can also mean tilt of the earth but that is also not explicit.

Because of the lack of explicit detail in the alternative related to the position of the earth, the best answer for this question would be the tilt of the earth. However, if the question is used again, there must be no ambiguity implicit in the words used in the alternatives.

Question five related to the free fall of objects. To make the question more relevant, the author presented a scenario where while making your way to a lecture, three objects (a pen, an eraser and a coin) fall out of a pocket at the same time. The question required the respondents to identify which of the objects would fall the fastest or if they would all fall together. The author listed the fourth alternative; i.e. all objects fall together as the correct option. A point of criticism may be that this is a weak answer because it does not say which object would reach the earth first or last; and if you take air resistance into account the objects would not reach the ground at the same time.

The fundamental concept being tested in this question five is whether students understand that all objects fall towards the earth with the same acceleration due to gravity (approximately $10 m/s^2$). Of course, the concept of air resistance is important as in the case of a sheet of paper, which has a large surface area. A sheet of paper will experience more air resistance than a pen when falling, and thus reach the ground later. However, if the objects do not have a large surface area, then the effects of air resistance are negligible as in the case of the three objects above and they reach the ground at the same time. In any event, the motion that was being analyzed was the simultaneous free fall. Nonetheless, the effects of air resistance and the sizes of objects must be carefully presented if this question is used again in a scientific literacy test.

Question six focused on the level of water in a container "decreasing" when the ice melts. A possible criticism is that while floating it (ice) displaces the amount of water to which it will melt, so the level of water will remain the same. The author offers the following rationale for stating that the volume of water will decrease when the ice melts:

Consider an ice tray with water before it is placed into a freezer. Suppose that the water level of each cube of water is the same as the height of the side of the tray. The water molecules in this liquid phase are in contact with one another. When the ice begins to freeze the amount of water in the tray does not increase but the volume of the cube expands, and the height of the cube is now higher that the side of the tray, the cube also expands onto the sides of the tray. This happens because as water turns to ice, the distance between the water molecules increases. Hence, its volume increases. The reverse of this process of ice making occurs when the ice melts in water. The volume of the ice in a liquid phase is less than that in a solid phase. Hence. the level of water should decrease when ice melts in water. Incidentally, the author conducted the experiment and confirmed that the level of water decreases when the ice melted. Nonetheless, the stem of this question was contentious as some say the level of water decreases and others say that it remains the same. However, that ice is less dense than water cannot be disputed, and this was the answer required of the students. Therefore, if the same concept is tested in the future, the question must not have a stem, which is so contentious.

Question seven concerned Newton's First Law of Motion; i.e. a body will remain in a state of rest or uniform motion in a straight line unless acted upon by a net or unbalanced force. A situation was presented where you are riding in a car, which swerved to the left and your body moves to the right. The author contended that the reason why the body moved to the right was because it wanted to continue moving in a straight line.

A point of criticism is that in the question and answers two systems are mixed up, the one of the passenger in the car and the other of the outside observer. Hence, in the first system the answer 3 (move to the right) will be correct, and in the second system the answer 4 (keep on going in a straight line) will be correct. It is highly possible that the question can be interpreted in these two ways. The author was fixed on the second system response and it seems as though the respondents were as well because 98.24% of the students selected "keep on moving in a straight line" as the correct answer. If the same question is used in the future, the criticism must be addressed.

Question 8 pertained to the pushing and pulling of objects. The author contends that it is easier to pull an object than to push it. Objects exert a downward force equal to their weight onto the ground. In return, the ground exerts a normal force, equal to the weight of the object, in an upward direction. When you push the object, you are exerting a downward and a horizontal force on the object. Thus, you are in fact pushing the object into the ground while trying to move it across the floor. This makes it difficult to push the object. When you pull an object, you are exerting a horizontal and an upward force on the object. Thus, you are pulling the object off the ground and trying to pull it across the floor. The combined upward force (normal plus the one you exert) makes it easier for you to pull the object across the floor, as there is less resistance with the floor.

Rather than complicate this question with the concept of normal force, the intention was to elicit, in a simple way, the understanding that the upward force is greater when you pull as opposed to when you push objects. The possible criticism is that this question cannot be answered without more information about the situation. For example, the points at which the forces act; the direction of the push and the pull; a drawing; and/or better description of the situation. These considerations must be made and incorporated into the revised question.

Question eleven related to the cellular respiration. The respondents were required to identify the by-products of cellular respiration. The most appropriate answer was CO2 and energy. A point of criticism is that water should have been included as part of the answer. At another level, we could specify ATP as a product, or add that heat could also be considered as a product of cellular respiration. At yet another extreme, we could consider NADH2 and FADH2 as products although they are consumed within the energy carrier system of cellular respiration. The point of the question was not to go into factual detail. Many students often confuse the processes of gaseous exchange with cellular respiration. The rationale for the question was to check whether students know that cellular respiration is similar to gaseous exchange, which releases CO2, but different to gaseous exchange in that energy is released during cellular respiration. It is apparent that many of the respondents had very little difficulty in figuring out the most correct response as 80.29 % got it right. Regardless, if the question is repeated in a scientific literacy test then water should be part of the answer.

Question eighteen concerned the identification of the best conductor of electricity as Silver not Copper. A possible criticism is that the differences between the electrical resistivity of Copper and Silver are marginal… so the properties of Copper are not far superior to that of Silver.

The question required the respondents to identify the "best conductor" of electricity. Rightly so, even though the difference is marginal, the answer is Silver. The rationale for including the question was not to test the level of detail in terms of electrical resistivity. Rather, the idea was to check the respondents understanding of conductivity of different elements, which is a feature in the General Science syllabus in South Africa. The reason why Silver is not used as extensively as Copper is simply because of the higher costs and the nature of the material. Nonetheless, the question will not be recommended for future tests of scientific literacy.

Lastly, question nineteen on colour of light is very interesting. It must be noted that these questions were informed largely by the syllabus documents for Science in South Africa. It is clear in the Standard 9 or Grade11 Physical Science Syllabus that when light passes from one medium to another (of different optical density) then its speed changes but its colour remains constant. This change in speed is brought about by a change in wavelength, not a change in frequency (note v = fh, where h represents lamda, the symbol for wavelength). Therefore, the colour of light is determined by its frequency not its wavelength. Some critics may argue that both wavelength and frequency determine the colour of light. This criticism must inform similar questions in future tests of scientific literacy.

The third limitation of this study concerned the literature review. There is a dearth of literature available on the technological literacy. There are two main reasons for this limitation. First, more attention has been focused on the concept scientific literacy that spawned the concept of technological literacy. Technological literacy is a relatively new concept compared to scientific literacy. The origins of the concept scientific literacy were traced back to the 1930's and the concept of technological literacy was only alluded to in the 1970's when the concept of practical scientific literacy was presented by Shen (1975, cited in Shamos 1995) [see Table 2.1. pp.29-32]. Second, technological literacy is commonly subsumed within the scientific and technological literacy discourse. Nonetheless, every effort was made to provide an insightful exposition of the different conceptions of technological literacy. This study contributed to the literature with the introduction of a new concept, namely intuitive technological literacy. It was proposed above in the section on recommendations related to the findings of this study that a curriculum be developed for technology so that it can be worthy of learning area status. It is recommended that concomitantly the process of development be documented and published to contribute to the limited literature available on technological literacy.

The fourth limitation is related to the research methodology of this study, which can be described best as the Mixed Methodology Design Model of combining qualitative and quantitative research methods. The mixed methodology method entailed mixing aspects of the qualitative and quantitative paradigm at all or many methodological steps in the design. This research methodology approach required a superior knowledge of both the qualitative and quantitative paradigms of research. However, the author was a novice qualitative and quantitative researcher, and the guidance and advice of the supervisor and the statisticians from the University of Pretoria proved invaluable. It is recommended that if the study is replicated or taken to scale that the same kind of support be available. It would be even better if expert qualitative and quantitative researchers can be part of the team that conducts the research and the analysis. These recommendations are being made because arriving at the principal findings associated with each question was a complex and onerous task. The process was extremely iterative and involved several consultations. With the involvement of experts at the coalface, the process would not only be more expeditious but the results will also be more reliable.

The fifth limitation of this study relates to the use of the SOLO Taxonomy for the classification of qualitative responses generated by the students. The use of the SOLO Taxonomy is simple and systematic; however, there are moments when you doubt your judgement, not at the first three levels of pre, uni, and multistructural responses, but more so at the fourth and fifth levels of relational and extended abstract responses. Sometimes, you encounter a response that lists a variety of factors extremely coherently and you are tempted to assign a score to that response which goes beyond the relational level. So you search desperately for any link to extended abstract ideas. Sometimes the link to abstract ideas is remote and you are tempted to force the classification at a higher level. Given such challenges associated with the use of the SOLO Taxonomy, it is recommended that for future studies, as we did for this one, that the researcher and supervisor agree on some common approach to classifying these higher level responses. What this limitation highlights is that the SOLO Taxonomy like other assessment models, is not a flawless approach. It is not immune to the subjective biases that one encounters when exercising qualitative judgements in other contexts where it is difficult to distinguish between two groups. Nonetheless, these are the exceptions and not the norm with the SOLO Taxonomy. By and large, it is a reliable method of systematically assessing qualitative responses.

It is unequivocal that there were many other limitations of this study; but the discussion was confined to the above five limitations, as they were the most challenging to the author.

7.6. Conclusion

As stated at the outset, South Africa is a fledgling democracy and needs to assert itself on many fronts. This study provided us with an opportunity to explore developments in the spheres of scientific and technological advancement, and in curriculum transformation. The implications of this study for each of these spheres will be elaborated.

With regard to scientific and technological advancement, my thesis is that to progress in this sphere, we need to assess where we are and use that result as a basis of making improvements. The methods used in this study to measure scientific and technological literacy levels have proved successful. We can now embrace these methods, revise them according to scale and need, and assess scientific and technological abilities. Once we establish where we feature as a nation on the barometer of scientific and technological literacy it will help us in two ways. First, it will explain our limitations as a nation to advance scientifically and technologically. Second, it will provide us with an opportunity to review our weaknesses as illustrated in the scientific and technological literacy tests, develop strategies to address the weaknesses, and evolve scientifically and technologically as a nation. The immediate benefit of this scientific and technological evolution lies in the empowerment of the general public to understand events and ideas related to scientific discovery and technological development, and thereby to exercise the rights and responsibilities of citizenship in a democratic society. At a stretch, I might add that economic prosperity will also follow but that hinges on other factors as well like a diligent and industrious society.

With regard to curriculum transformation, my thesis is that we need to explore all viable options in the pursuit of a successful educational system. The transition from a traditional behaviorist curriculum to a progressive outcomes-based education paradigm has been a difficult process in South Africa. This study showcased how traditional practices still dominate the teaching and many learning practices associated with science in our schools. Curriculum transformation will continue to throw many curved balls our way in our pursuit of a perfect educational system for South Africa. As we are in the throes of reforming C2005, and because the SOLO taxonomy has proved successful in this study, it could provide South Africa with a simple method of facilitating learner performance reviews and learner progression as recommended above. The SOLO Taxonomy is an alternative worth pursuing in light of the lack of grade-based benchmarks against which to assess learner performance in South Africa.

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QUESTIONNAIRE FOR FIRST YEAR SCIENCE STUDENTS

Researcher : F. Goolam
Supervisor: Annemarie van Loggerenberg
Institution: University of Pretoria

This questionnaire collects information about first year science students' levels of scientific literacy; the extent to which they apply science and technology in their everyday lives; and biographical information about the respondents.

This study could result in improved science teaching and learning practices at secondary schools.

The respondents can rest assured that all information from the questionnaire will be treated in the STRICTEST CONFIDENCE.

Please answer all the questions by circling the appropriate number in a shaded area or writing your answer in the shaded space.

PLEASE LIST YOUR STUDENT REGISTRATION NUMBER BELOW BEFORE ANSWERING ANY QUESTIONS.

A.	Registration number								V1:1-7

PART 1: QUESTIONS ABOUT SCIENCE

Question 1: The Chemical Compound that is responsible for global warming is…

Choices

NH_3	O_2	N_2	CO_2
1	2	3	4

V2:8

Question 2: The weathering of concrete structures exposed to rain may be as a result of water combining with…

Choices

NH_3	SO_2	CH_4	Fe
1	2	3	4

V3:9

Question 3: The chemical substance that protects the earth from harmful ultra violet rays…

Choices

CO	CO_2	O_2	O_3
1	2	3	4

V4:10

Question 4: Seasonal change on earth is caused by…

Choices

The rotation of the earth	The position of the earth relative to the sun	The tilt of the earth	The position of the earth relative to other planets
1	2	3	4

V5:11

Question 5: While making your way to a lecture, three objects, a pen, an eraser and a coin, fall out of your pocket at the same time. As you watch them fall you notice…

Choices

The pen falls fastest	The eraser falls fastest	The coin falls fastest	All objects fall together
1	2	3	4

V6:12

Question 6: When ice melts in a container of water, the water level decreases because…

Choices

Ice is equally dense as water	ice is more dense than water	ice is less dense than water	the statement is untrue
1	2	3	4

V7:13

Question 7: When you are seated in a car and it swerves to the left, your body moves to the right because your body wants to…

Choices

stop moving	move to the left	move to the right	keep on going in a straight line
1	2	3	4

V8:14

Question 8: It is easier to pull than to push an object because the net force exerted by the ground…

Choices

Increases	Decreases	remains constant	the statement is untrue
1	2	3	4

V9:15

Question 9: When catching a cricket ball, the pain experienced by the hand can be reduced if the time taken to stop the ball…

Choices

Increases	Decreases	remains constant	the statement is untrue
1	2	3	4

V10:16

Question 10: When salt is added to a cooking vessel, the boiling point of its contents...

Choices

Doubles	Decreases	remains constant	increases
1	2	3	4

V11:17

Question 11: The by-products of cellular respiration are…

Choices

O_2	CO_2	CO_2 and energy	Energy only
1	2	3	4

V12:18

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Question 12: 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

V13:19

Question 13: A synthetic product can be described as a strong acid if its pH is…

Choices

6	7	14	1
1	2	3	4

V14:20

Question 14: Chemical reactions in the body are influenced by enzymes as the rate of reactions…

Choices

Double	decrease	remain constant	increase
1	2	3	4

V15:21

Question 15: The AIDS virus is transmitted during…

Choices

Saliva exchange if there are abrasions in the oral cavity	Sexual intercourse	Intravenous blood transfusion	All of the above
1	2	3	4

V16:22

Question 16: The unit in which electricity is bought from power suppliers is …

Choices

Kg	W	Cd	kWh
1	2	3	4

V17:23

Question 17: 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

V18:24

Question 18: The best conductor of electricity is…

Choices

Cu	Ag	Fe	Au
1	2	3	4

V19:25

Question 19: Which one of the following properties determines the colour of light?

Choices

Wavelength	frequency	speed	velocity
1	2	3	4

V20:26

Question 20: A ball is dropped from a height above the ground, it falls and bounces back to …

Choices

The original height	< the original height	> the original height	the original height repeatedly
1	2	3	4

V21:27

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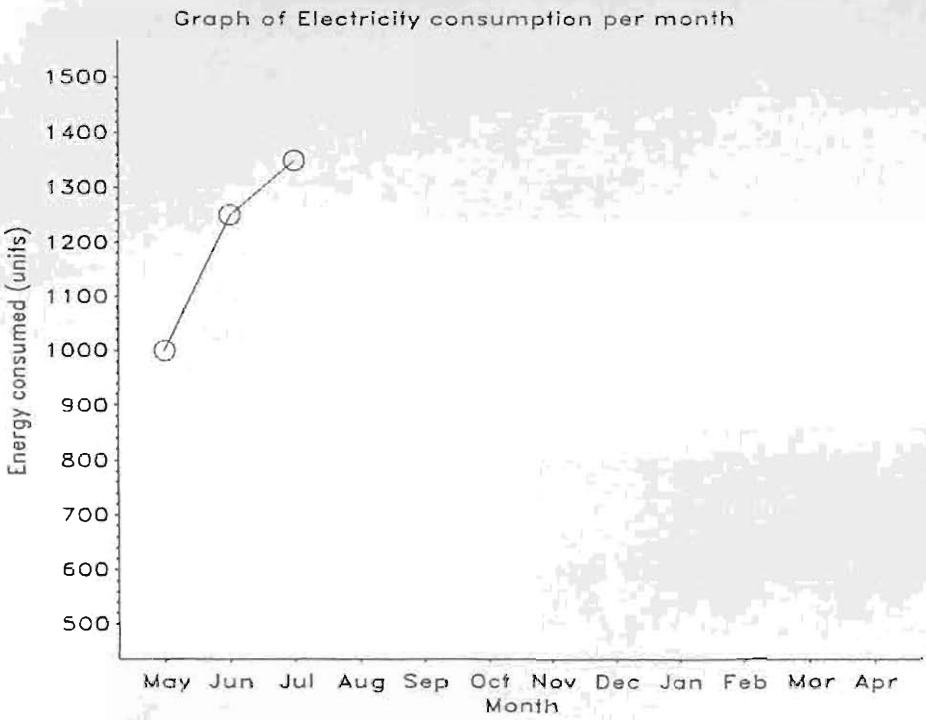
PART 2: QUESTIONS ABOUT SCIENCE IN OUR EVERYDAY LIVES

Task 1: 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.



V22:28-29
V23:30

Provide reasons for changes to the shape of the graph:

V24:31-32
V25:33

Task 2: Briefly describe the technological factors that you would take into consideration before purchasing a cell phone, and justify your selection of factors?

V26:34-35

V27:36

Task 3: Discuss the impact of the internet on society:

V28:37-38

V29:39

Task 4: Should the drug AZT be made available to pregnant women in South Africa?

V30:40-41
V31:42

Task 5: Provide an illustrated example of an indigenous (home-grown) form of technology that you have experienced in South Africa.

V32:43-44
V33:45

Task 6. Suppose that the U[illegible]d to embark on an active campaign of community service and enlisted the support of its students. You have been requested to assist with resolving sanitation problems at an informal settlement for a population of 100 residents. You have the daunting task of applying your knowledge and understanding of sanitation issues to develop a system that is cost effective and convince the local community that the system that you develop is in their best interest. Prepare a detailed description of how you would approach this challenge. Your response should be restricted to a page and include details on:

Investigations Pursued:

V34:46-47
V35:48-49
V36:50-51
V37:52-53
V38:54

Design and Planning:

V39:55-56
V40:57-58
V41:59-60
V42:61-62
V43:63

Modifying Systems to Suit Contexts:

V44:64-65
V45:66-67
V46:68-69
V47:70-71
V48:72

Sensitivity to the Issues and Choices in the Community of Informal Settlers:

V49:73-74
V50:75-76
V51:77-78
V52:79-80
V53:81

Final Recommendation:

V54:82-83
V55:84

PART 3: QUESTIONS ABOUT YOU:

1. What is your name?

2. What is your age in completed years?

V56:85

3. What is your gender?

Male	1	Female	2

V57:86

4. What is your first language (the language you use **most often**)?

English	1
IsiZulu	2
SeSotho	3
IsiXhosa	4
Afrikaans	5
Setswana	6
Other (specify)	

V58:87

5. Are you willing to be interviewed for this study?

Yes	1	No	2

V59:88

If "**Yes**", please provide a contact number below.

6. Name the last school that you attended?

V60:89

7. Where is the school located e.g. Diepkloof?

V61:90

8. In which province is your school situated?

V62:91

9. How would you describe the area in which your school is situated?

City	1
Suburb	2
Township	3
Farm	4
Other (specify)	

V63:92

10. Select the former department that your school was affiliated to?

DET (Urban African Schools)	1
HOD (Indian Schools)	2
HOR (Coloured Schools)	3
DEC (Homeland African Schools)	4
HOA (White Schools)	5
Other (specify)	

V64:93

11. Describe the physical resources of your school using the table below?

Physical resource	Excellent	Good	Poor	Not available	
Electricity	1	2	3	4	V65:94
Laboratories	1	2	3	4	V66:95
Text book supply	1	2	3	4	V67:96
Teaching aids (charts etc)	1	2	3	4	V68:97
Furniture (desks & chairs)	1	2	3	4	V69:98

12. Complete the following table for subjects taken in matric?

Subject	High	Std	Lower	Symbol
English	1	2	3	
Physics	1	2	3	
Mathematics	1	2	3	
Biology	1	2	3	
Geography	1	2	3	
Other subjects (specify)				
a.	1	2	3	
b.	1	2	3	
c.	1	2	3	
d.	1	2	3	

V70:99
V71:100
V72:101
V73:102
V74:103
V75-V86
104-107
108-111
112-115
116-119

13. How many learners were in your matric science class?

V87:120

14. What was the medium of instruction in your matric science class at school?

English only	1
English & your 1st language	2
Your 1st language only	3
Other (specify)	

V88:121

15. Indicate how often you experienced each of the following kinds of teaching in science at matric level?

Kind of teaching	Always	Most times	A few times	Never
Mainly chalk and talk	1	2	3	4
Use of textbooks to explain	1	2	3	4
Questions and answers	1	2	3	4
Problem solving	1	2	3	4
Science experiments	1	2	3	4
Work in small groups	1	2	3	4
Other(specify)	1	2	3	4

V89:122
V90:123
V91:124
V92:125
V93:126
V94:127
V95-V96
128-129

16. To what extent were each of the following learning methods encouraged in science classes at school?

Learning Method	Always	Most times	A few times	Never		
Memorize notes & equations	1	2	3	4		V97:130
Solve problems using numbers only	1	2	3	4		V98:131
Solve problems using concepts and principles	1	2	3	4		V99:132
Solve problems using concepts and principles	1	2	3	4		V100:133
Solve problems using numbers, concepts and principles	1	2	3	4		V101:134
Use your own ideas to understand new information	1	2	3	4		V102:135
Relate physics to real life	1	2	3	4		
Other(specify)						V103-V104
	1	2	3	4		136-138

17. What degree are you registered for at University?

B.Sc	1		V105:139
B.Sc. Engineering	2		
B. Paed	3		
Other (specify)			

18. Select the subjects (course ?

Course	Taken this year	Taken last year	
Physics 1	1	2	V106/107:140-141
Chemistry 1	1	2	V108/109:142-143
Mathematics 1	1	2	V110/111:144-145
Biology 1	1	2	V112/113:146-147
Applied mathematics 1	1	2	V114/115:148-149
Computer science 1	1	2	V116/117:150-151
Engineering drawing	1	2	V118/119:152-153
Geography	1	2	V120/121:154-155
Other (specify)			V122-V136
a.	1	2	156-159
b.	1	2	160-163
c.	1	2	164-167
d.	1	2	168-171
e.	1	2	172-173

Thank you for responding to the questions posed above. You will be briefed about the findings distilled during the synthesis of data. If you are unhappy with any aspect of the work, it will be revisited as you specify. I once again wish to remind you that all information retrieved from the questionnaire will be treated in the strictest confidence.

Appendix 2

Focus Group Interview Schedule

Instructions:

a. Quickly decide how the following roles will be assigned in your group of five students:
Gatekeeper: ensures that each member has an equal opportunity to participate.
Scribe: summarizes the main points raised in the discussions.
(Rotate these roles for each of the questions provided below.)

b. Discuss each of the questions listed below in your groups and provide responses in the spaces provided. There could be more than one response per question if the group decides that more than one answer is correct.

c. Circle the correct answers in the table below before attempting the questions:

Group No:	1	2	3	4	5
Course:	PHY101		PHY171		

QUESTIONS:

1. Define the following terms:

a) Scientific Literacy:

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b) Technological Literacy:

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2. Explain how you would determine whether your friend, colleague or parent is:

a) scientifically literate:

b) technologically literate:

3. How do you use science and technology in your everyday lives? For example, what scientific principles are applied while driving a car or when preparing meal? N.B. PLEASE USE YOUR OWN EXAMPLES!

4. 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?

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5. In the questionnaire that you completed earlier this year, you encountered several challenges. Some of these challenges included determining 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. Discuss these challenges in your group and provide a joint response to each challenge.

a) AZT availability to pregnant women:

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b) Cell phone technological factors:

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c) Impact of the Internet on Society

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Observer Schedule

Observer Name:							
Observer Registration Number:							
Group No:	1	2	3	4	5		
Course:	PHY101	PHY171					

The observer plays the most critical role in the execution of this focus group interview as s/he will objectively record the group dynamics that are associated with the development of responses to the questions in the focus group interview schedule. The observer must remain with the group that s/he has been assigned to at all times. The observer is kindly requested to complete the following frequency table during observations.

N.B. The observer will also be the Timekeeper, i.e. ensure that the same amount of time is allocated to each question.

The following key will guide the completion of the table below:

Level of Participation: 1 – Poor (NO suggestions or questions per Group discussion, readily accepts group response contribution)
2 – Satisfactory (1 or <1 suggestion or question per Group discussion, readily accepts group response)
3 – Average (1 to 2 suggestions or questions per Group discussion, challenges group response at least once)
4 – Good (3 to 4 suggestions or questions per group discussion, challenges group response 3<1 times)
5 - Excellent (>4 suggestions or questions per group discussion, challenges group response >3times, leads the discussions)

Use of Science Concepts: 1 – Poor knowledge of science concepts
2 – Lists scientific terms without explaining them
3 - Lists the scientific terms and explains them
4 – Links scientific knowledge coherently
5 – Talks about science at an abstract level

Use of Technological Concepts
1- Cannot apply scientific concepts in real life situations
2- Applies scientific concepts to real life situations satisfactorily
3- Applies scientific concepts to real life situations well
4- Can debate the advantages and disadvantages of technology e.g. AZT and cell phones
5- Can discuss the impact of technology e.g. the internet

Group member	Level of Participation					Use of Science Concepts					Use of Technological Concepts				
1	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

The observer is also required to provide a description of each of the following:

a) how consensus was reached in the group,

b) the kinds of challenges encountered in each of the groups.

Appendix 3. Analysis of Focus Group Interviews

N.B. These are actual responses of the focus groups.

#	Course	# of Students	Scientific Literacy	Technological Literacy	Use of Science in Everyday Life	Enable Scientific and Technological Literacy	AZT	Cell Phone	Internet
1a	PHY 101	3	Is the understanding of science and its application on a daily basis TEST: The way he looks at things and if the person has an enquiring mind.	It's the understanding of technology like electricity and its understanding by the ordinary people and also electricity TEST: If a person is exposed to technological appliances and knows how to use them in a daily basis.	We use science to measure the speed of anything which is in motion. We can use technology to communicate in everyday lives e.g. cell phones. Newton's laws of motion can be used to turn the steering wheel of a car.	We must give more practical examples that are applied daily and which they can understand better.	Yes, it must be available in order to lower the rate of babies born with HIV virus	More functions that are available on the cellphone, quality of the battery, the capacity of the cell to store data.	It has given people easy access to informat ion.
1b	PHY 101	4	a process whereby information about science is given TEST: By asking whether they understand the concepts/scientific processes that take place in our everyday lives. E.g how does it come about to rain	Is a process whereby how science works in an everyday life TEST: Through questioning them to see whether they know how to use technological equipments (sic) like computers.	Putting a plug into a socket to use electricity. Switching a light on/off.	Educate people about how science and technology work like introducing scientific equipments (sic) to them. Encourage them to participate in scientific events.	If it is used to protect women and their babies during their pregnancy then it should be made available.	A cell phone is the easier way to communi cate, if there are disadvan-taged factors they would be improved.	No response

#	Course	# of Students	Scientific Literacy	Technological Literacy	Use of Science in Everyday Life	Enable Scientific and Technological Literacy	AZT	Cell Phone	Internet
1	171	1	To know the science of the earth and understand it and you can apply the laws of science. TEST: I would ask him why does an apple fall from a tree. If he know it is scientific he knows something scientific.	You can use modern technology like VCRs and computers. If the computer is broken you can sort of know what the problem is and fix it. TEST: It is easy to see. If he can program a VCR and know how to use a computer and try to be technological advancing everyday.	I program on a computer. Science is used when I am ryding my bike from home to university like taking a corner	I would give free internet to everyone.	It is their right, if they want to use it they must know the consequences.	If you want someone urgently you can get them easier on their cellphone	If you want inform-ation of everything you can get it there and you don't have to drive to the place to get them (sic)

2a	PHY 101	5	The understanding of science in general e.g. reading, using equation, doing, experiment and observation and applying these in real life. TEST: If the person is able to figure out any problem without a solution by himself using his common sense e.g. throwing grass in the air to determine the direction of the wind.	The understanding of technology in general and being able to use or operate modern systems e.g. TVs, computers, etc. TEST: By being able to use technological devices in everyday life. Like using cellphones and manual.	Being cautious of electric appliances. For instance, when baking with an electric stove using right degrees.	I could introduce more training/technical centres where learning is more practicaly oriented	AZT is giving lives to many babies who could have died.	Encourages communica tion. It's faster to get a message across.	Safes time. More info in a short time.

2b	PHY 101	5	Books, literacy, etc. that has something to do with science. It is explained in scientific terms and language. Ideas and concepts in science – what question we have and what the answers is to that question concerning science TEST: They must have the basic understanding about science. They must also be interested in the field of science. Take their lifestyle into consideration – what do they do, read – how do they interpret things in life. What ideas do people have	Literacy that has to do with new discoveries and technological advances. How things are put together and how they work and why they work. How technology is used in our everyday life. TEST: The person must be computer literate. They must be able to know about the latest technology. See if they use the latest technologically advanced cellphones, computers, tvs	Technology: Computer for e-mail, TV, cellphones. Scientific: When taking a photograph - (lenses) create a focal point. Electricity.	Provide free computer lessons. Science and technology must be introduced in Primary schools to enable the learners to have a basic understanding.	Yes, it should be available to all pregnant women with HIV/AIDS Because why should you have two dying persons instead of one.	Communication is an important factor in our lives. Look at battery time, talk time, if it can fax, e-mail, the size.	Persons can have more information. It is also negative because any information can be put on the Internet without supervision.

2a	PHY 171	3	Good scientific knowledge. To be able to understand scientific terms. If you are given a scientific book, the person should be able to understand what everything in the book means and to have discussion with other scientific literate persons and understand what they are talking about. TEST: Whether or not she understand scientific meanings etc when you have a discussion with them.	To be able to use technology and understand how it works e.g. computer etc TEST: If the person knows and understands and doesn't struggle in using technological equipment like computers, cellphones, calculators, microwaves.	Calculators, computers, security doors, alarm. heaters and fans – heat energy current resistors. Alarm: sensory devices electric.	Offer them free workshops and tours of technology museums and shows. Anything that will interest them and entertain them.	(Yes) because it lowers the risk of their unborn child contracting AIDS.	…for business: with internet and inter-national calls… for personal: voicemail, and voice dial, picture messaging, and games etc.	The Internet has made it possible for commun ication across the world and disabled people who can't get out of the house can do shop-ping on the internet and doctors for research purposes .

2b	PHY 171	4	An understanding of general science, physics, chemistry or natural sciences etc. Basic understanding of the jargon. TEST: …by listening to their explanations (of) scientific topics and also by judging them by their habits and interests.	Be able to use and feel comfortable with technological equipment and able to adapt to advancements thereof. And a basic understanding of the jargon. TEST: They are comfortable around new technology and can easily adapt and learn how to use technological equipment.	The use of electricity, Using computers and the Internet. The cooking of food.	Supply electricity to all parts of the country. Move programmes and promotions to inform and educate the citizens about how technology can impose their lives. In educating them about technology you educate them about science.	AZT should be available enabling the women to choose if she wants to use it.	SMS, internet access, large broadcast area. The battery should be able to last a long time.	Globalization, knowledge is more readily available Positive effect on the economy, use of e-commerce. E-mailiing speeds up communication and is cheaper.

3	PHY 171	3	Applying mathematical principles to the real world, towards benefit of mankind. TEST: They can help with your physics homework	Programming a VCR. Being able to use electronic appliances. TEST: Knowing the terminology e.g. MB = megabyte, and not act damaging towards technological appliances.	Most principles are instinctive (and)iour subconscious (sic). We don't feel we actually benefit from our studies in physics…	Firstly, not group arts and science…	Our govern-ment believes that HIV does not cause AIDS!!! Poverty does…	They cause cancer due to radiation.	Degrada-tion of society towards deca-dence

3	PHY 101	5	The knowledge and understanding of scientific terminologies and theories and the application thereof. TEST: We would determine this by their interests, literature read, television programmes watched, basic scientific knowledge, and if they can relate to a conversation about science.	The awareness of Technological advances in the fields of mechanics and electronic advance, and the ability to use, apply and improve on these theories. TEST: Whether the person is able to use and understand basic everyday technology. How to operate a calculator, computer, cell phone, TV, microwave oven, VCR.	A roller coaster ride. Crossing a road – you judge the speed and distance, time, of the car approaching, if you'll be able to cross safely.	Making scientific equipment available to students at primary school level by making (it) part of the curriculum. Motivating the students and encouraging them to get scientific interests at an early age by science fairs, expos, and school practicals. Make science expos appeal to people of al ages, races and financial status.	Yes (3) and No (2). Yes =having morality and compassion and the possibility of saving a child's life. No = There is a high possibility that the mother will die and the child will survive, thus leaving an orphan-chain reaction.	…size of screen and phone, settings, battery life and accessories available.	The impact is great because of the avail-ability of all the inform-ation, good and bad. Good – social-izing, support groups, shop-ping, educatio nal. Bad- porno-graphy, crime, drugs and explosiv es and credit card fraud.