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.

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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 Paper. 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).

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[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"*
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> (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. <u>The Purpose of this Study</u>

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 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).

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 science 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.