

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. Underpinning Learning Theory

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. Motlala (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. Goals

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 of 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 Jeevananthan (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. Teaching Strategies/Methodologies

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 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.

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?

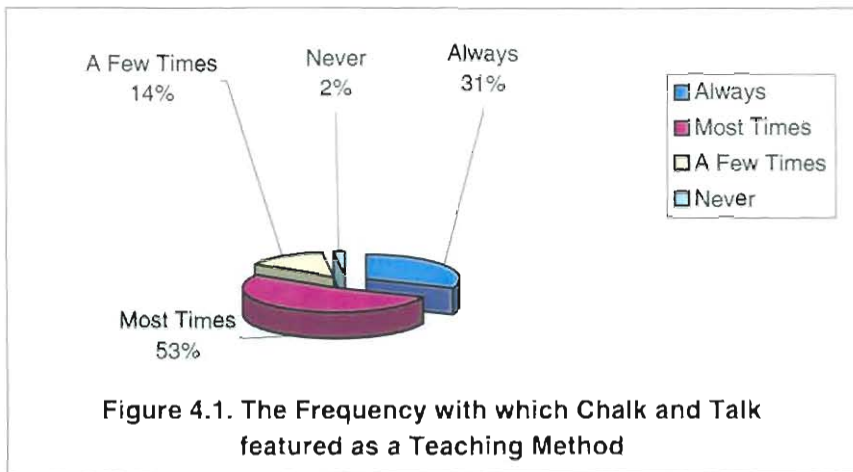
4.3.1. The Kinds of Teaching Experienced by the Students

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

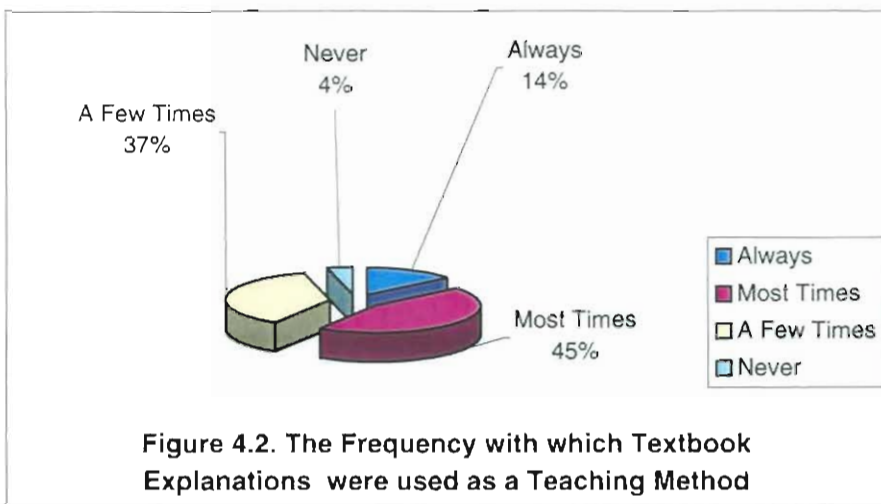
The frequency descriptors which students were provided with for each of these kinds of teaching were: always; most times; a few times; and never. A frequency description will follow for each kind of teaching. Thereafter, the results will be discussed using selected elements of the comparison of the traditional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

4.3.1.1 Mainly Chalk and Talk



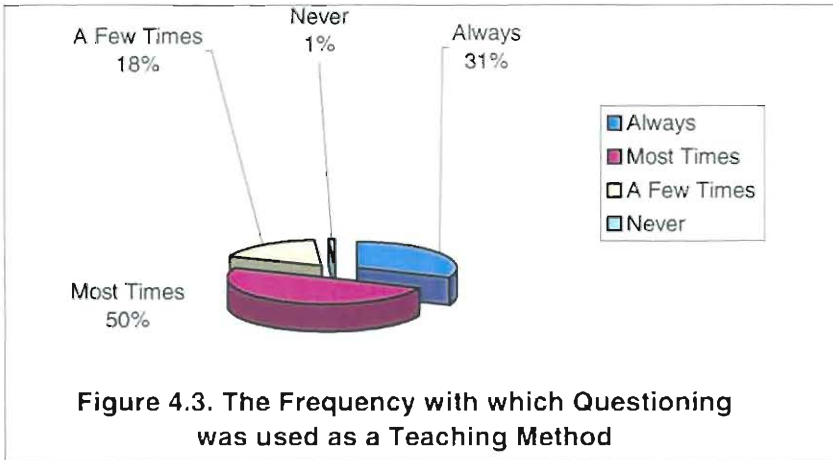
Chalk and talk was an extremely popular method of teaching amongst the students. 31 % of the students claimed that this was always the method of teaching, and 53 % stated that chalk and talk was used most times. A mere 14 % maintained that they were exposed a few times to the chalk and talk method, and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

4.3.1.2 Use of Textbooks to Explain



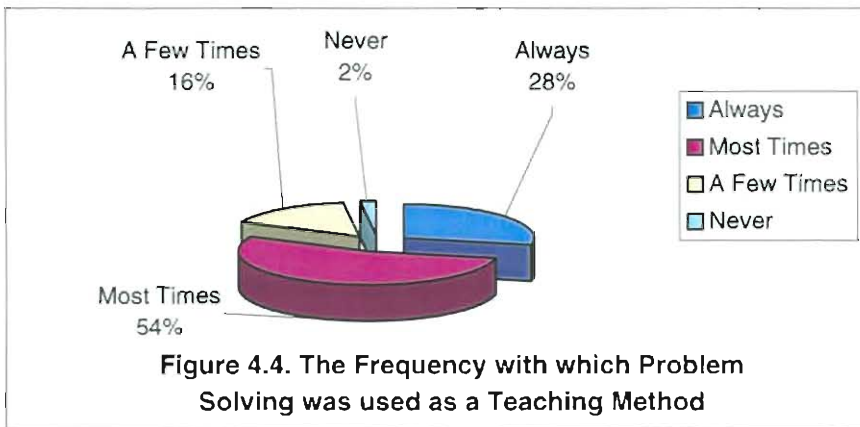
Textbook explanations were not as popular as chalk and talk, but it did feature quite often in the teaching practices experienced by the students. 14 % of the students declared that they always experienced this kind of teaching, 45 % experienced it most times, 37 % a few times, and 4 % were never exposed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

4.3.1.3. Questions and Answers



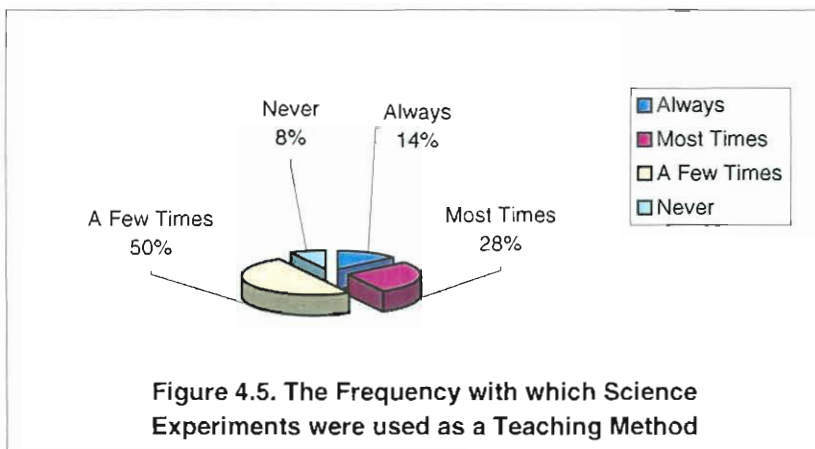
The questions and answers approach to teaching was as popular a teaching method as chalk and talk. 31 % of the students asserted that they always experienced this kind of teaching, 50 % experienced it most times, 18 % a few times and 1 % were never exposed to this kind of teaching.

4.3.1.4. Problem Solving



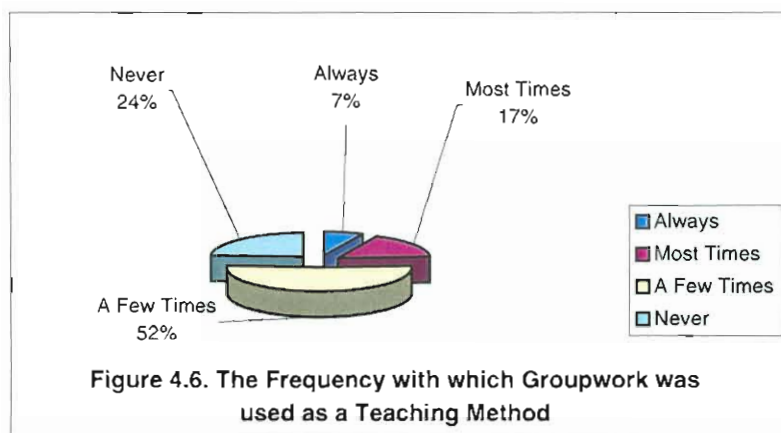
Problem solving also featured conspicuously as a common method of teaching amongst students. There appears to be a clustering of scores for the three most common types of teaching that students were exposed to. These common types in order of decreasing popularity, albeit by small margins, were chalk 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. Science Experiments



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. Working in Small Groups



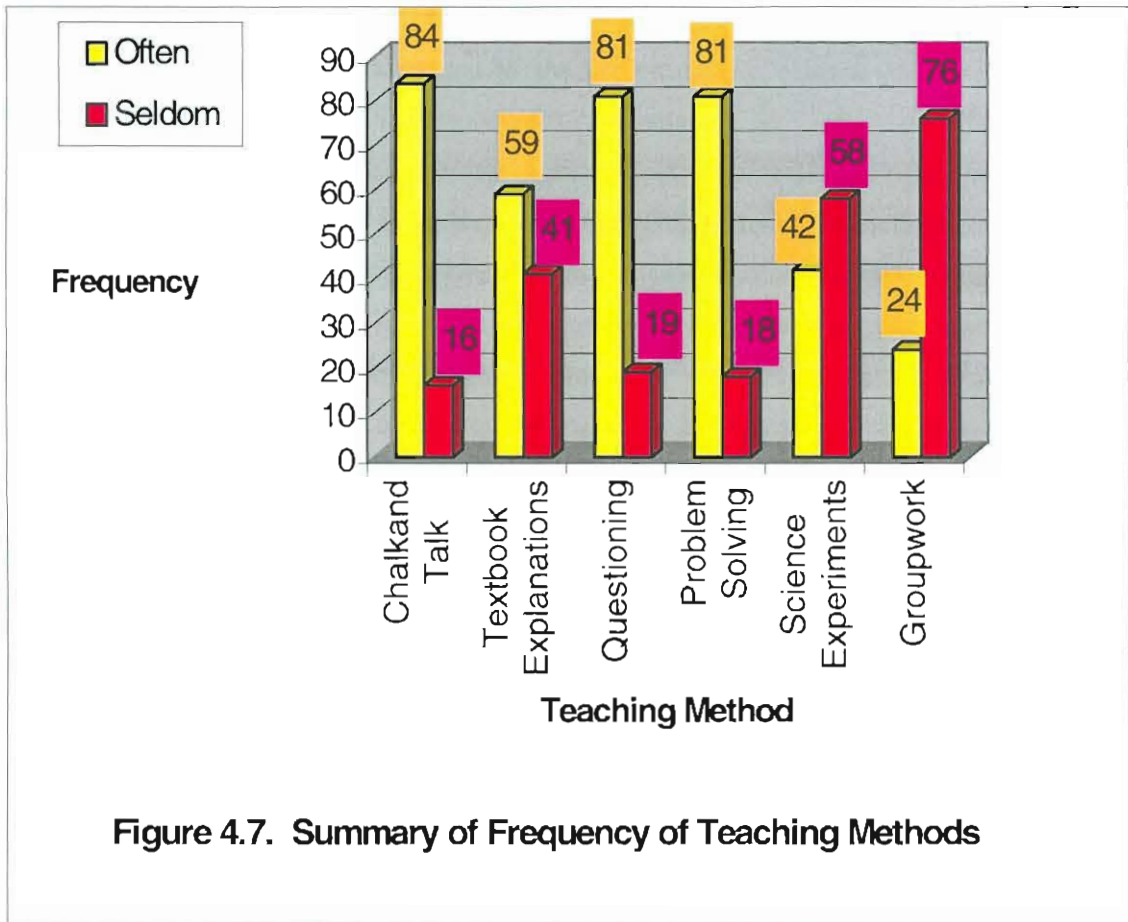
This method of teaching was the least popular of all methods. 7 % of the students declared that they always used group work as a method of teaching, 17 % experienced it most times, 51 % a few times and 24 % were never exposed to this kind of teaching.

4.3.1.7. Other Teaching Methods

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.



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.

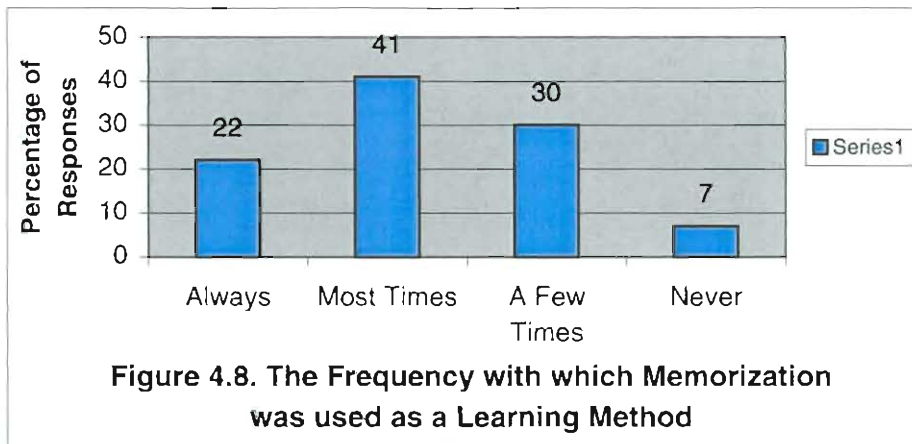
4.3.2. The Kinds of Learning Experienced by the Students

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.

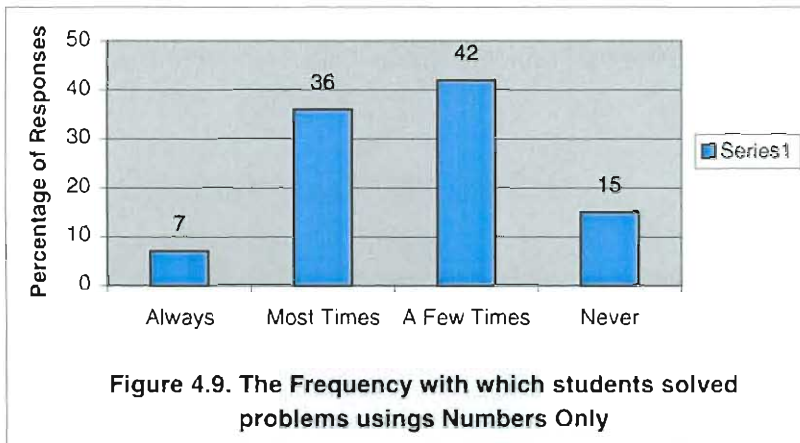
The frequency descriptors which students were provided with for each of these kinds of learning were: always; most times; a few times; and never. A frequency description will follow for each kind of learning. Thereafter, the results will be discussed using selected elements of the comparison of the traditional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

4.3.2.1. Memorize notes and equations



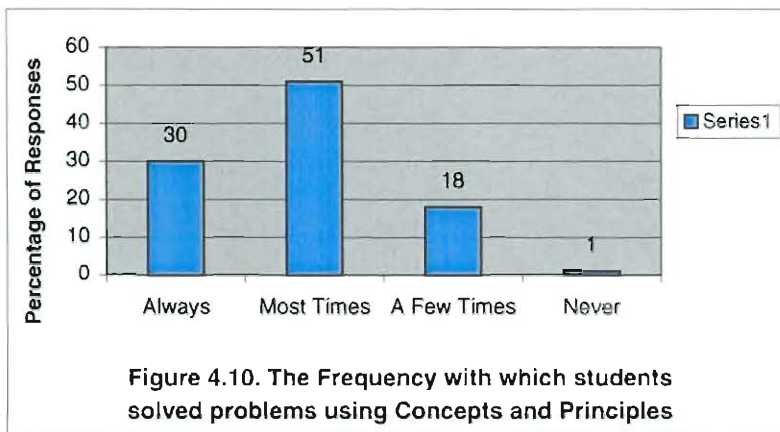
Unexpectedly, the memorization of notes and equations did not show similar high frequencies as did its teaching methodology ally, chalk and talk. 22 % of the students claimed that they always experienced this kind of learning, 41 % experienced it most times, 30 % a few times, and 7 % were never exposed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

4.3.2.2. Solve Problems using Numbers Only



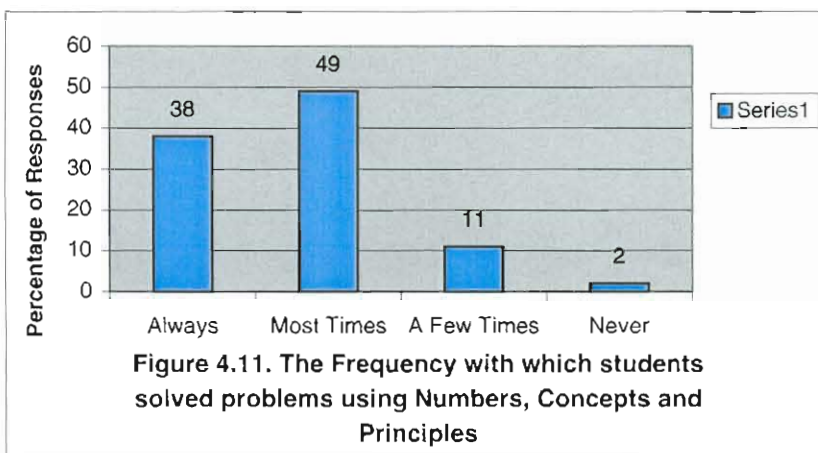
This was the least popular method of teaching. The frequency counts for problem solving exclusively with numbers reflect that a mere 7 % of the students declared that they always used this method of learning, 36 % experienced it most times, 42 % a few times and 15 % never used this kind of learning.

4.3.2.3. Solve Problems using Concepts and Principles



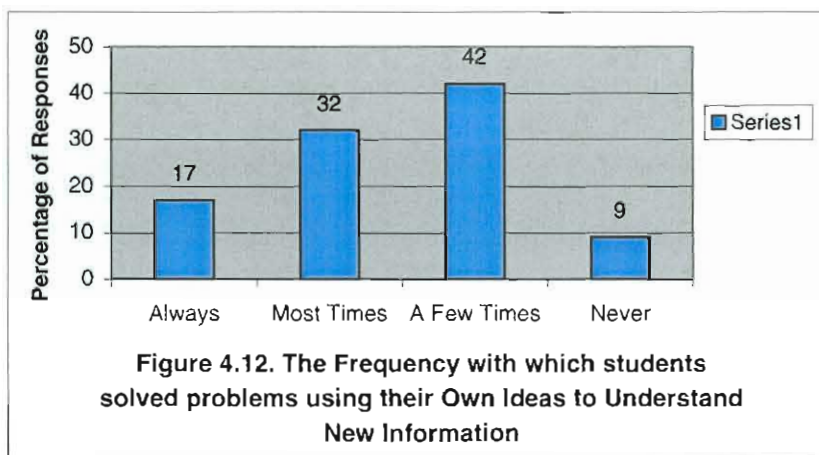
The use of concepts and principles to solve problems represents a higher order of understanding than simply inserting figures into equations. It was therefore very encouraging to note that this higher order level of learning was more frequently in use amongst the students. 30% of the students claimed 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



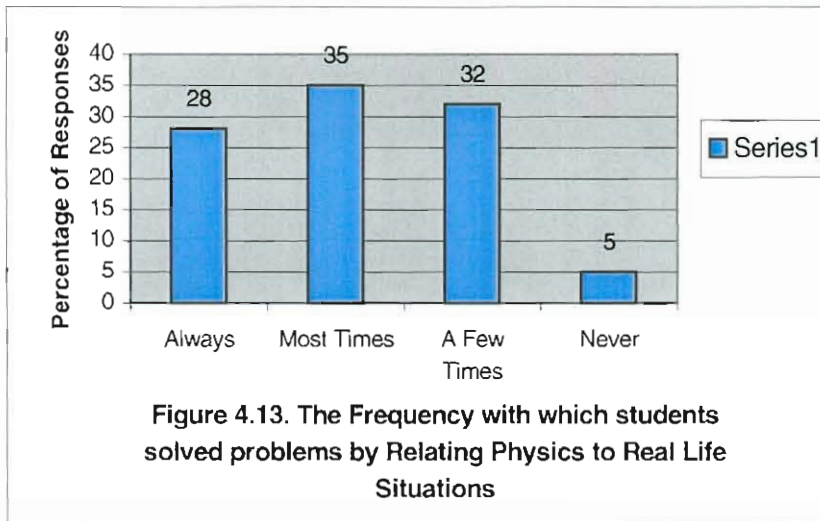
This was the most popular method of learning that the students claimed to have used. This category is actually a conflation of b) and c) above and one would therefore expect a combined result for this type of learning, but that was not the case. 37% of the students maintained that this was always the 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



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



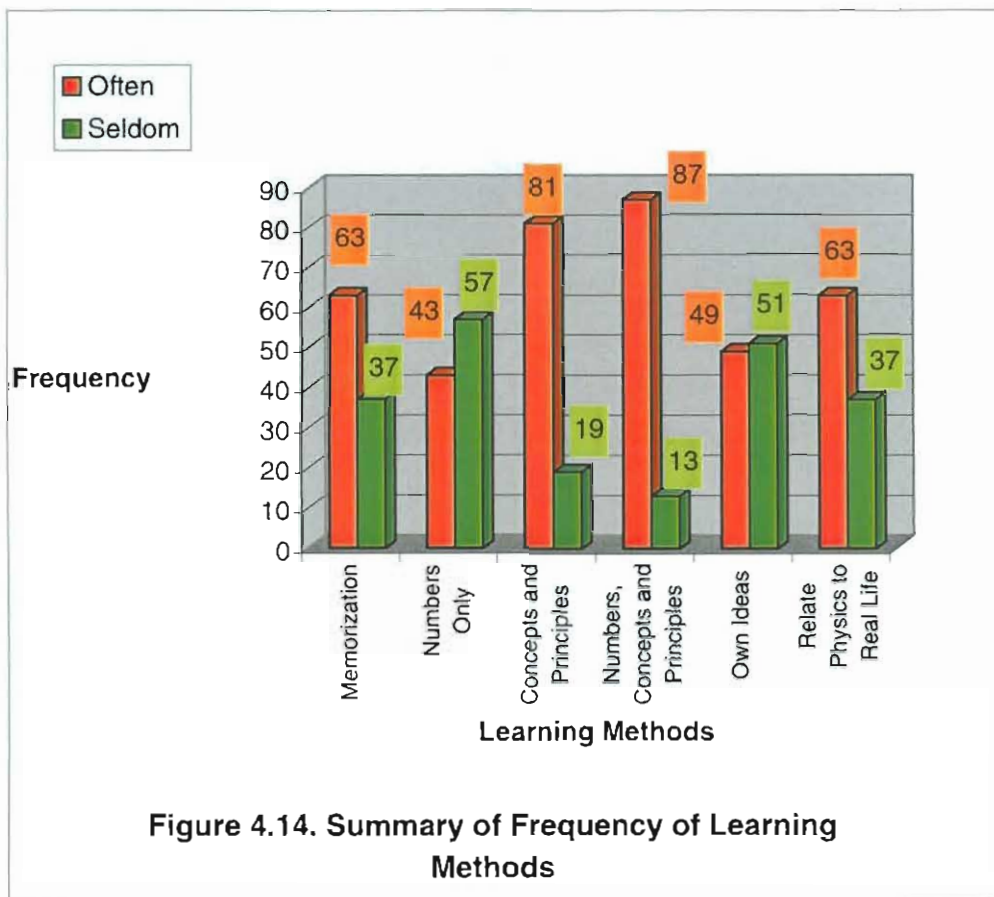
This method of learning was moderately popular with 28 % experiencing it always, 35 % using it most times, 32 % a few times and 5 % never used this method of learning.

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.



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 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? 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, 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 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.