# A FRAMEWORK FOR THE PLACEMENT OF UNIVERSITY STUDENTS IN SCIENCE PROGRAMMES

by

**MELANIE JACOBS**
(BSc; BEd; BOptom; MPhil (Optometry); PGCE)

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|---|---|
| **PROMOTER:** | **Prof. G. P. de Bruin, UJ** |
| **CO-PROMOTERS:** | **Dr. S. P. van Tonder, UFS** |
| | **Dr. M. C. Viljoen, UFS** |

# DECLARATION

I hereby declare that the work which is submitted here is the result of my own independent investigation. Where help was sought, it was acknowledged. I further declare that the work is submitted for the first time at this university towards the Philosophiae Doctor degree in Higher Education Studies and that it has never been submitted to any other university for the purpose of obtaining a degree.

M JACOBS

03 December 2010
DATE

I hereby cede copyright of this thesis in favour of the University of the Free State.

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"So that it may be made clear that this extraordinary power belongs to God and does not come from us."
(2 Cor. 4:7b)

**Dedicated to Gerrie, Minette and Gerrit**
**(with love)**

# CHAPTER 1

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| | |
|---|---|
| AARP | Alternative Admissions Research Project |
| ACT | American College Test |
| AL | Academic Literacy |
| ANOVA | Analysis of variance |
| APS | Admission Points Score |
| AT | Access Test |
| BEE | Black Economic Empowerment |
| BQ | Biographical Questionnaire |
| BTI | Basic Trait Inventory |
| BTI-SF | Shortened version of the BTI |
| CAMP | Cognitive Academic Mathematical Proficiency |
| CESM | Classification of Educational Subject Matter |
| CHC | Cattell-Horn-Caroll |
| CHE | Council on Higher Education |
| CHED | Centre for Higher Education Development |
| CHET | Centre for Higher Education Transformation |
| CTP | Committee for Technikon Principals |
| CUT | Central University of Technology |
| DoE | Department of Education |
| DoHET | Department of Higher Education and Training |
| EM | Enrolment Management |
| ESC | Enterprising, Social, Conventional |
| FET | Further Education and Training |
| FYE | First Year Experience |
| GPA | Grade point average |
| GRE | Graduate Record Examination |
| HDT | Historically Disadvantaged Technikons |
| HDUs | Historically Disadvantaged Universities |
| HE | Higher Education |
| HEI(s) | Higher Education Institutions |
| HEQC | Higher Education Quality Committee |
| HESA | Higher Education South Africa |
| HG | Higher Grade |
| HSPT | Health Sciences Placement Test |
| HSRC | Human Sciences Research Council |

| | |
|---|---|
| HWUS | Historically White Universities |
| HWT | Historically White Technikons |
| IELTS | International English Language Testing Service |
| KPIs | Key Performance Indicators |
| MACH | Maths Achievement |
| MBA | Masters of Business Administration |
| MCOM | Maths Comprehension |
| MEDUNSA | Medical University of South Africa |
| NBT | National Benchmark Test |
| NC | National Certificate |
| NCHE | National Commission on Higher Education |
| NCS | National Curriculum Statement |
| ND | National Diploma |
| NEO-PI | NEO Personality Inventory |
| NEO-PI-R | Neuroticism Extraversion Openness - Personality Inventory Revised |
| NMMU | Nelson Mandela Metropolitan University |
| NPHE | National Plan for HE |
| NRF | National Research Foundation |
| NSC | National Senior Certificate |
| OBE | Outcomes Based Education |
| OCEAN | Openness to Experience, Conscientiousness, Extroversion, Agreeableness and Neuroticism |
| PTEEP | Placement Test in English for Educational Purposes |
| QL | Quantitative Literacy |
| QPU | Quality Promotion Unit |
| RSA | Republic of South Africa |
| SA | South Africa |
| SAIRR | South African Institute of Race Relations |
| SAT | Scholastic Aptitude Test |
| SATAP | Standarised Assessment Tests for Access and Placement |
| SAUVCA | South African Universities' Vice Chancellors' Association |
| SC | Senior Certificate |
| SERTEC | Certification Council for Technikon Education |
| SET | Science, Engineering and Technology |
| SFP | Science Foundation Programme |
| SG | Standard Grade |
| SOM | Study Orientation in Mathematics |

| | |
|---|---|
| SOMT | Study Orientation in Mathematics Tertiary |
| SU | Stellenbosch University |
| SweSAT | Swedish Scholastic Aptitude Test |
| SYSTEM | Students and Youth into Science, Technology, Engineering and Mathematics |
| TEEP | Test for English in Educational Purposes |
| TELP | Tertiary Education Linkages Project |
| TIMSS | Trends in Mathematics and Science Study |
| TOEFL | Test of English as a Foreign Language |
| UCT | University of Cape Town |
| UDW | University of Durban Westville |
| UFS | University of the Free State |
| UJ | University of Johannesburg |
| UK | United Kingdom |
| UKZN | University of KwaZulu-Natal |
| UN | University of Natal |
| UNIFY | UNIN Foundation Year |
| UNIN | University of the North |
| UP | University of Pretoria |
| UPFY | University of Pretoria Foundation Year |
| USA | United States of America |
| UWC | University of the Western Cape |
| WITS | University of the Witwatersrand |
| WPHE | White Paper 3 on HE transformation |

# ABSTRACT

In view of the government policy directives to broaden access, of especially students in Natural Science (hereafter referred to as Science) and to increase student throughput, a quantitative study was undertaken to identify indicators of academic success, in order to develop a framework for placement. The first-year curriculum of programmes in Natural Science, Engineering and Health Sciences all include Mathematics, Chemistry and Physics as core fundamental Science modules. Academic student achievement pertaining to these three modules, were considered to design a framework for placing students in appropriate programmes.

The national shortage of Science skills and higher subsidy from government prompt universities to change current curricula. When exploring success indicators of university Mathematics, Chemistry and Physics, the schooling system comes to the fore. The shortage of qualified teachers, constantly changing school curriculum and poorly resourced schools becomes evident in the quality of knowledge and skills of first-year students entering universities.

This quantitative study focuses on the academic achievement of first-year students in the three fundamental modules, based on curricula that are developed and embedded in content and skills acquired at school level. The university curriculum continues from the perceived school exit level. Very few changes were made to first-year curricula, yet the school curriculum and student profiles changed considerably. The high failure and drop-out rate strengthens the rationale for this research. The study investigated placement of first-year students in appropriate programmes, in order to enhance academic success. In a study of policy documents, literature and empirical research on academic achievement, no other reference to a framework for placement could be found.

In order to design the framework the research focused on two types of sources, namely, a literature study on South African Higher Education, and general mental ability and non-cognitive influences on academic success. This highlighted the importance of specific abilities and interests that are key to Mathematics and Science. Students in the fields of Natural Science, Engineering, Health Sciences as well as teachers and lecturers in these fields, come from a very limited pool, and special care, planning and management of such students, teachers/lecturers and academic programmes are required. Universities have no choice but to adjust current curricula, practise innovative enrolment management and render time and support to ensure an increased graduation rate in these fields.

An empirical study was conducted on the academic achievement of four cohorts of first-year Science students at the University of Johannesburg, in Gauteng, South Africa. The link between the background variables (gender, age, home language and ethnicity) and the influence of Grade 12 results were shown to be associated with academic achievement in Mathematics, Chemistry and Physics at first-year level. Home language, ethnicity and Grade 12 Admission Point Score (APS) contributed significantly towards predicting academic achievement. The Stellenbosch University Access Test had good predictive value, and in conjunction with the Grade 12 profile, it could be

applied meaningfully to place students in appropriate programmes. The inclusion of non-cognitive instruments provided significant insight to place students, based on informed decisions.

The findings of both the literature and empirical study were structured in six categories which formed the foundational principles of the conceptual framework for placement: i) Neither the influence of the South African schooling system, nor the curriculum or quality of students will change in the foreseeable future; ii) Universities should collect as much as possible knowledge of students to promote quality learning and provide them with support; iii) Structured support and institutional First-Year Experience programmes will assist students with the adjustment from school to university; iv) Higher Education should urgently consider alignment with the entry-level of students and establish generic programmes to introduce them into universities; v) Opportunities to articulate from generic programmes to specialised qualifications with additional support for acquiring English language proficiency, computer and academic literacies as well as career guidance will be of utmost importance to provide Science graduates to assist with national needs; and vi) Students will be successful if specialised lecturers and methodology are employed for first-year teaching of complex disciplines.

The proposed framework was designed, based on the above foundational principles and supported by four guidelines for implementation, namely: i) the establishment of a first-year enrolment centre with one-stop service and support; ii) a well designed extended qualification with a generic entering phase; iii) time allocated (during the generic phase) to assess individual students with a compound test battery; and iv) specialised methodology, a dedicated teaching and learning strategy with dedicated first-year lecturers to promote academic achievement in Science.

The study culminated in the framework for placement for Science students, after admission. The theoretical implication of the proposed framework is represented by the holistic lens through which the field of Science was researched, culminating in common Mathematics, Chemistry and Physics attributes. Its practical implication focuses on changed perceptions and practices embedded in first-year lecturers and university managers. The conceptual framework promises to change minds, attitudes and practices on placement and includes the responsibility to inform knowledgeable university colleagues. Those embarking on future research relating to this theme can build upon this study, while placement in Science education should stimulate the development of theory and practice and can be tested in Higher Education.

# OPSOMMING


In die lig van die regering se beleidsrigting om toelating studente in Natuurwetenskappe (hierna verwys as Wetenskappe) te verbreed, asook om die deurvloei van studente te verhoog, is hierdie kwantitatiewe studie onderneem om indikators vir akademiese sukses te identifiseer, ten einde 'n raamwerk vir die plasing van eerstejaarstudente te ontwikkel. Die eerstejaarkurrikulum in Natuurwetenskappe, Ingenieurswese en Mediesverwante studievelde sluit almal Wiskunde, Chemie en Fisika as fundamantele modules in. Akademiese prestasie van eerstejaarstudente ten opsigte van hierdie drie modules is ondersoek, ten einde 'n raamwerk te ontwerp waarmee hulle in toepaslike programme geplaas kan word.

Die nasionale tekort aan wetenskaplike vaardighede en verhoogde regeringsubsidies dwing universiteite om huidige kurrikula te wysig. Toeligting van die indikatore vir sukses in Wiskunde, Chemie en Fisika op universiteitsvlak plaas die huidige SA-skoolstelsel onder die soeklig. Die tekort aan gekwalifiseerde onderwysers, voortdurende verandering van die skoolkurrikulum en 'n tekort aan noodsaaklike hulpbronne, is veral opvallend in die kwaliteit van eerstejaarstudente wat tot universiteite toetree.

Die fokus van hierdie kwantitatiewe studie is veral die prestasie van eerstejaarstudente in die drie fundamentele modules. Die Hoëronderwyskurrikulum in hierdie dissiplines is tradisioneel 'n voortsetting van die inhoud, vaardighede en konsepte wat tydens die skooljare gevorm en vasgelê word. Weinig aanpassings is aan eerstejaarskurrikula aangebring alhoewel die skool kurrikulum en studenteprofiel indringende verandering ondergaan het. Die hoë druipsyfer en groot aantal studente wat hul studies staak, versterk die rasionaal vir hierdie navorsing. Hierdie studie ondersoek plasing van eerstejaarstudente in gepaste programme, ten einde groter sukses te verseker. 'n Bestudering van beleidstukke, literatuur en empiriese navorsing oor die akademiese sukses van eerstejaarstudente onderstreep die noodsaaklikheid van die daarstelling van 'n raamwerk. Die literatuurondersoek het aangetoon dat daar nie tans 'n raamwerk vir plasing bestaan nie.

Vir die ontwerp van die raamwerk is gefokus op twee tipes inligtingsbronne. 'n Literatuurondersoek oor Suid-Afrikaanse Hoër Onderwys en die rol van verstandelike vermoë, asook nie-kognitiewe faktore as aanduiders van akademies sukses met betrekking tot Wiskunde en die Wetenskappe. Die ondersoek het getoon dat 'n klein geselekteerde groepie studente oor die vermoë en uiteindelike belangstelling beskik om te volhard in studies in die Natuurwetenskappe en verwante studierigtings. Spesiale bestuur van en ondersteuning vir sodanige studente is noodsaaklik vir die suksesvolle opleiding van Natuurwetenskaplikes, Ingenieurs, Mediese praktisyns en onderwysers in hierdie studievelde. Universiteite het geen keuse nie as om bestaande kurrikula en bestuurspraktyke, te hersien om die inkomende studente-profiel te akkommodeer, ten einde genoegsame tyd en ondersteuning te bied om die oorgang vanaf skool te belyn, en om sodoende suksesvolle studente as graduandi te lewer.

Die empiriese navorsing uitgevoer met gegewens soos ingesamel vanaf vier kohorte van eerstejaarstudente aan die Universiteit van Johannesburg, Gauteng Suid-Afrika. Die ondersoek het die skakeling tussen agtergrond-veranderlikes soos geslag, ouderdom, huistaal en etniese groepering gemeet teen eerste semester prestasie in die drie bovermelde fundamentele modules. ’n Belangrike bevindig was dat huistaal en etniese groepering beslis as sukses-aanduiders in ag geneem behoort te word. Die empiriese ondersoek het ook getoon dat die Graad 12-Toelatingspunttelling (TPT), wel betroubaar aangewend kan word in die voorspelling van eerstejaarprestasie. Die Universiteit van Stellenbosch se Toegangstoetse het baie goeie voorspellingswaarde en kan tesame met die Graad 12-profiel sinvol aangewend word om studente in toepaslike programme te plaas. Nie-kognitiewe instrumente het ook ‘n betekenisvolle bydrae gelewer wat met groot vrug aangewend kan word as deel van omvattende toetse en plasing op grond van ingeligte besluite.

Die gevolgtrekkings van die literatuurstudie en empiriese ondersoek is in ses kategorieë gegroepeer. Hierdie kategorieë is saamgevoeg om die funderingsbeginsels van die Plasingsraamwerk te vorm, naamlik: i) Die invloed van die SA-skoolstelsel, kurrikulum en die kwaliteit van studente wat aan universiteite gelewer word, sal nie in die nabye toekoms verander nie; ii) Universiteite sal uitgebreide kennis oor studente moet verkry, ten einde te verseker dat kwaliteit leer en ondersteuning kan plaasvind; iii) Ter ondersteuning van studente sal universiteite gestruktureerde eerstejaarsprogramme moet aanbied om die oorgang vanaf die skool na die eerstejaar te belyn; iv) SA Hoër Onderwys sal dringend generiese intreeprogramme moet oorweeg sodat studente met generiese modules kan begin, waarna hulle na gespesialiseerde programme kan artikuleer; v) Ingeslote in die generiese fase moet studente Engelse taalvaardigheid, rekenaar- en akademiese geletterheidsondersteuning ontvang, asook kundige beroepsvoorligting ondergaan; en vi) Gespesialiseerde eerstejaarsdosente (met ‘n onderbou in die metodologie van die dissipline) moet geselekteer word om hierdie komplekse dissiplines te doseer.

Die voorgestelde raamwerk is ontwikkel uit vier riglyne wat gerugsteun word deur voorvermelde beginsels, naamlik: i) die strukturering van ‘n Eerstejaarstoelatingsentrum met ‘n eenstopdiens en ondersteuning; ii) die deurdagte ontwerp van ‘n verlengde kwalifikasie met ‘n generiese intreefase; iii) genoegsame tyd vir die assessering van individuele studente (met ‘n verskeidenheid toetsbatterye); en v) gespesialiseerde metodologie, asook ‘n toegewyde onderrig- en leerstrategie met geselekteerde spesialis-eerstejaarsdosente om akademiese uitnemendheid in Natuurwetenskappe te bevorder.

Die studie bou op na die daarstelling van ‘n raamwerk vir plasing van Natuurwetenskapstudente. Die teoretiese implikasie van die voorgestelde raamwerk is gesetel in die navorsing se holistiese fokus op Natuurwetenskappe. Verskeie gemeenskaplike eienskappe van Wiskunde, Chemie en Fisika ondersteun mekaar en word nie in isolasie ondersoek nie. Praktiese implikasies fokus hoofsaaklik op veranderde persepsies van eerstejaarsdosente en universiteitbestuurders. Die konseptuele raamwerk hou die belofte in om die denke, houdings en praktyke oor plasing en die verantwoordelikheid van kundige universiteitkollegas toe te lig. Verdere navorsing sal ook voortgesette teorievorming stimuleer en in die Hoër Onderwyspraktyk getoets kan word.

# KEY CONCEPTS

- **STUDENT PERFORMANCE**
- **STUDENT PLACEMENT**
- **FRAMEWORK**
- **HIGHER EDUCATION**
- **HIGHER EDUCATION POLICY**
- **INDIVIDUAL DIFFERENCES**
- **FIRST-YEAR SUCCESS**
- **FIRST YEAR (STUDENT) EXPERIENCE**
- **FUNDAMENTAL SCIENCE MODULES**
- **STUDENT ACCESS**
- **STUDENT ADMISSION**
- **STUDENT SUCCESS**
- **SCIENCE EDUCATION**

# CHAPTER 1

## *CONTEXT OF THE PROBLEM, CONCEPTUAL ANALYSIS AND PURPOSE OF THE STUDY*

### 1.1 INTRODUCTION

The South African Higher Education context has changed considerably over the past sixteen years. The transformation of the country is also visible in the Higher Education enterprise. Broadening of participation with more students accessing universities and the subsequent challenges faced by institutions, such as student retention of and maintaining high standards, are increasing. This research focuses on academic achievement of first-year students in Science programmes, specifically in academic programmes that require Mathematics, Physics and Chemistry at first-year level.

The specific emphasis on the aforementioned fundamental Science modules can be ascribed to the importance of these modules in various programmes within Natural Sciences, Health Sciences, Engineering and related programmes. The high level of student failure accompanied with an increased drop-out rate is problematic in Higher Education and especially important in Natural Science (hereafter referred to as Science) programmes. Over many years models of student admission and selection have been widely researched internationally (Astin 2005:5-17, Pascarella & Terenzini 2005) and in South Africa over decades (Huysamen and Raubenheimer 1999:132, Maree 2003a:19-25, Yeld 2009a and Foxcroft 2009). Predictors of academic success have been identified with students in America having written admission tests since 1926 (Murphy & Davidshofer 1998:394). The American system places students at different levels and in most curricula students start by studying generic and basic programmes in 'college' (Astin 2005:5-17). Appropriate placement of admitted students is a more recent, often neglected, yet much desired research domain in South Africa (Foxcroft 2009). The integration of the existing body of knowledge and the challenge of responsible placement after admission only recently attracted the attention of researchers (Nel & Kistner 2009:953-973; Yeld 2009a; Van der Merwe & De Beer 2006:547-560).

It is against this background that the need for an in-depth study of the optimal placement of students in Science programmes is identified. It is hoped that the development of a framework may guide further research and practice in the field of student placement. The proposed framework for the placement of students is an attempt to accommodate the contemporary demand for inclusivity (i.e. accommodating students with a broad range of academic preparedness skills for post-school study), and the demand that students should finish their qualifications in the minimum timeframe.

This first chapter serves as an introduction of the context of Science in Higher Education in South Africa and the purpose and rationale of the study. This chapter will conclude with an overview of the research methodology and demarcation of the investigation.

## 1.2 CONTEXT OF THE STUDY

In order to describe the context of this research an analogy of a funnel will be used. The funnel contains a wide range of elements found in South African Higher Education (Figure 1.1). The various elements are filtered through the funnel. The force of gravity exerts downwards and separates the elements into three distinguished layers. The first of the three layers to be examined is the overarching South African Higher Education context, while the next layer thins down to specifically Science in Higher Education. The final layer in the core of the funnel represents the performance of first-year students in Science programmes.

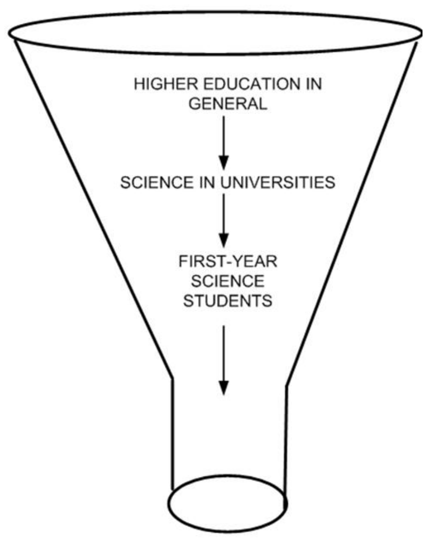


***Figure 1.1*** **Elements present in SA Higher Education**

### 1.2.1 Future challenges of South African Higher Education

The South African Higher Education sector has undergone major changes since 1994. Policies and directives have redefined Higher Education thereby influencing the sector itself, individual institutions and ultimately, students.

The South African Higher Education sector is steered by government through policies that direct processes and procedures in the sector. The Department of Education (DoE) promulgated The

White Paper (1997a), The Higher Education Act (1997b), and The National Plan on Higher Education (2001) among others, focusing on widening of access. Participation of specifically Black students is prominent, as are the efficiency and quality of academic programmes, the change in government funding criteria (2003a) and provision of graduates within a minimum timeframe (2004a).

Major implications of policies focussed on the Higher Education sector are firstly, a decrease in the number of institutions from 36 (in 2003) to 22 (in 2005), mainly via mergers of traditional universities with one another or with technikons (RSA DoE 2002a). Among others, this restructuring created 'comprehensive' institutions with degree and diploma options within one university. Secondly, the responsiveness to global economies is emphasised increasingly (RSA DoE 1997a), and thirdly, the mergers focused on corporate governance of institutions and institutional planning (RSA DoE 1997b).

The government subsidy granted for students to study Sciences is proportionally higher than for studies in Education, Humanities or Law (cf. Table 2.2), whereas expenses pertaining to these programmes are reflected by a reimbursement from government. Science studies require laboratories, expensive equipment and well qualified lecturers, technicians as well as continuous research. If students thus terminate their studies ('dropping-out') it results in a waste of own money as well as institutional resources. Ultimately, the Minister of Higher Education and Training will be accountable to taxpayers.

Higher Education institutions reacted to the above policy directives with an increase in first-year enrolments (cf. Table 3.2 p109; Scott in Bitzer 2009 and UJ 2009c). Management of student enrolment is a directive from the Department of Education (1997b) and requires strategic planning and action. Admission criteria and practices start the enrolment process, which then progresses to management of throughput and retention. This study focuses on placement, as part of admission, of first-year students, traditionally based on final school results. First-year students entering the Higher Education sector from the schooling system have high expectations of being successful in their studies. Furthermore, universities expect such students to enter with competencies and skills for becoming successful students.

The South African political transformation has impacted severely on socio-economic circumstances, specifically the educational dispensation. Inequalities that existed previously have not yet been eradicated. Student drop-out is increasing steadily (Bunting 2004a; University

World News 28 October 2009:9; The Times 25 July 2009:1 and Scott in Bitzer 2009:22). Another concern is the fact that students who terminate their studies or ‘drop out’ have little to show other than loan debts committed when they were still hoping to become an accountant, engineer or a doctor. Although first-year students’ success-rate has been a concern for many years (Bunting 2004a:73-94; Scott 2009 and Bitzer 2009:21-25), the past few years have prompted serious reflection on admission practices, teaching and learning approaches and other factors that might impact on students’ academic success.

Although more learners are admitted by universities than before, there are still discrepancies in the preparation of such learners for Higher Education (Foxcroft 2009; Nel & Kistner 2009:962-970 and Yeld 2009a). International and national practitioners have viewed the performance in final school assessment to be a satisfactory predictor of academic success in Higher Education (Astin 2005:5-17; Eiselen 2006:1; Huysamen 1999:132-138 and 2002a:139-147; Huysamen & Raubenheimer 1999:132-138; Jackson & Young 1988:170-175; and Koch & Foxcroft 2003:192-208). However, the past few years have resulted in the Higher Education sector losing confidence in the predictive value of school results (Nel & Kistner 2009:962-970; Bunting 2004a:73-94 and Bitzer 2009:21-22; Foxcroft 2009; Yeld 2009a and 2009b). As a result of school examinations and performance losing credibility, the focus should thus be on the current school systems.

Given the inequalities in schools, universities are faced with the challenge to adapt strategies to provide support and assistance to new students, as the school system is not deemed to be able to eradicate deficits in the near future. The impact of the policies also addresses students and provides increased opportunities for study. An increasing number of students must be funded while studying. Although a priority towards the recruitment of students in scarce fields such as Science, Engineering and Technology (SET) has been advocated, the pool of students from which Sciences (i.e. Natural Sciences, Agricultural Sciences, Information Technology, Engineering and Health Sciences) recruit prospective students, is limited. One of the reasons for the diminishing numbers in Science students can be found in the lack of qualified and trained teachers to teach Science at school level (cf. Maree 2009:261-264).

### 1.2.2 The status of Science programmes in South African Higher Education

The importance of Science as a national asset cannot be denied. Natural and related Sciences provide the country with medical doctors, engineers, scientists and farmers. The government is driving the recruitment of students in Science with increased subsidies granted to universities for successful graduates in Sciences (DoE 2003a). Universities are obliged to manage enrolments in Science and ensure successful throughput as Science fields (Natural Sciences, Engineering, Mathematical Sciences, Health Sciences, IT and Agricultural Sciences) have been placed in a higher bracket for earning government funding (DoE 2003a). Another impetus towards the above argument is the identification of Science competency as a scarce skill (DoE 1997a) and the national need to train scientists, engineers and other related professionals.

Access into studies in Science and other related disciplines, all rely primarily on school performance in Mathematics and Physical Science. In turn, Grade 12-results depend on the quality of teaching, commitment of the teacher and the learning attitude and environment created within schools. The throughput in Science is directly related to prior knowledge and skills of entering students, who should have acquired a certain level of competency at school (Beeld 9 April 2009c:1; The Times HE Supplement 25 July 2009:1). Lecturers in fundamental Science modules (e.g. Mathematics, Physics and Chemistry) have been assuming foundational content knowledge as a given trait of school leavers, and lecturers proceed with university teaching from this assumed basis. Failing first-year students are not a new discovery (Bunting 2004a:73-94; Scott 2009 and Bitzer 2009:21-25), but when the majority fail (Potgieter 2009, Engelbrecht, Harding and Phiri 2009:289-300, Maree 2009:264), lecturers are questioning admission requirements.

In the previous dispensation, the schooling system in South Africa was divided on racial, language and socio-economic grounds and fragmented in different sub-units (DoE 1999 and Jansen 1995). The inequalities were visible in the distribution of resources, opportunities provided to learners and the quality of teachers (Matoti & Lekhu 2008:126-142). It is unfortunate that many of these inequalities have not been eradicated, and that there are still schools where learners are not provided with opportunities to pursue further studies. Teachers are obliged to teach under trees, often without electricity, running water or sanitation (Matoti & Lekhu 2008: 126-142). The lack of qualified teachers is creating an even greater problem. Rademeyer (2009:396) reports that in 2004, there were 27 000 public schools in the country, with 17 985 qualified Mathematics teachers. These statistics indicate that there are proportionally 0.67 qualified Mathematics teachers per school. The fact that according to the National Curriculum Statement (DoE 2003b) all learners have to select either Mathematics or Mathematical Literacy up to Grade 12 aggravates this problem. How can less than one qualified teacher teach Mathematics to an entire school?

In general, the profile of teaching as a profession is not the preferred career choice of top achievers at school. Hence, finding qualified and passionate Mathematics and Science teachers to serve in the public schooling system also challenges Faculties of Science at South African universities. If we do not have teachers who cultivate an interest in Science, we will not have students studying in these fields. The Higher Education sector already has acutely experienced the inadequate preparation of students, especially when they enter in the first year.

### 1.2.3 Student performance in South African Higher Education

Finally, the third layer in the funnel represents the core of this study, namely the performance of first-year students in fundamental Science modules. This study will probe the high failure rate of students in Science, Engineering and Health Sciences and the perceived under-preparedness of first-year students who enter universities. Recent research suggests that the 'gap' between school and first-year at university is not only related to the difference in culture, socio-economic circumstances or differences in the content being covered. All first-year students arrive at universities with 'capital' to be spent. This 'foreign currency' is packaged as knowledge, skills, experience and talent (Van Zyl 2009). Universities determine the exchange rate and must be able to distinguish between the 'have' and 'have not' students. The 'have' students arrive from schools having had exposure to resources (functional buildings, laboratories and electricity) (Jansen 1995:202-216) and qualified teachers (Rademeyer 2009:395). The 'have not' students suffered severely, having been exposed to poor teachers, shocking facilities and insufficient resources. These and many other factors indicate the varying levels of readiness of students in Higher Education.

The fact that first-year Mathematics (and similarly, Physics and Chemistry) builds on content, competencies and skills developed (or not) at school level is now contentious (Potgieter 2009; UJ 2008b; Engelbrecht *et al*. 2009:289-300). If students enter (many more enrolments than before) and fail (many more than before) the Higher Education sector has to react (Bitzer 2009:21-25). South African universities are currently developing strategies to ensure that students who are admitted are retained in the system. Furthermore, Higher Education South Africa (HESA 2006) is relatively advanced with implementing the National Benchmark Test (NBT) to provide information on prior knowledge and abilities of entering students. First-year lecturers have been revising their own teaching strategies to adapt to the seeming under-preparedness of students. Hence, Faculties of Natural Science are embarking on reviewing first-year curricula, in order to better align these with the National Curriculum Statement (NCS).

With the change of the school curriculum in 2003 (DoE 2003b and 2003c), and the first cohort of prospective first-year students with the National Senior Certificate (NSC) entering universities in 2009, nobody knew what to expect from this new 'phenomenon'. The level and content could not have been benchmarked or researched prior to this, and therefore required intense investigation. No longer do racial barriers keep students from studying and succeeding in Science, as has been the case almost two decades ago. Students can now enter universities more freely as more of them adhere to admission requirements, and many more pass Grade 12 Mathematics (Volmink 2010). Sadly, many more students also encounter problems within the first months of their university career (Yeld 2009a, Engelbrecht *et al.* 2009:288-302, and Nel & Kistner 2009:953-973).

Successful throughput of students challenges institutions to manage enrolment (Cronjé 2004) and to develop strategies to ensure student success and retention. The high drop-out rate (Bunting 2004a:73-94) has already resulted in the design of extended qualifications and foundational provision for under-prepared students accessing Higher Education from the fragmented school system (RSA DoE 2006b; Eiselen 2006:45-60; Foxcroft 2009; Grayson 1996:993-1013; Grussendorff, Liebenberg & Houston 2004:265-272; Hay & Marais 2004:59-75; Kersop 2004:34-67; Strydom 1997, UCT AARP-report 2004; to mention but a few). Furthermore, the 2009 cohort of students entered Higher Education from an 'unknown' national school examination into the first year, once again challenging institutions to rethink "access for success".

The current tendencies in Higher Education urge institutions and specifically faculties involved with Science to investigate admission and progression of students. There is a wide discrepancy between the Grade 11-symbol (which determines conditional admission to the university) and the final Grade 12-results (when the student registers at university) (Nel & Kistner 2009:964). In addition, there has been a shift in the target market of the university towards admitting more first generation students. These students experience a lack of academic support and financial aid. Finally, the impact of unqualified teachers and the shortage of Science and Mathematics teachers have been evident in the performance of students entered into Science programmes in Higher Education (Engelbrecht *et al.* 2009:289-300, Maree 2009:261-264 and Potgieter 2009).

This study proposes that students be placed after admission and assessment of individual strengths and weaknesses. In the light of the absence of an existing framework to address the performance and placement of first-year students, an investigation into the academic success of students in overarching Science programmes is thus deemed necessary.

## 1.3 PURPOSE OF THE STUDY

In the light of the background provided above, the principal purpose of this research was to develop a framework for the placement of first-year students in Science programmes.

### 1.3.1 Research goals

The research goals of this research were:

- To base the development of the framework on a literature review on Higher Education in general.
- To probe South African Higher Education policies specifically to determine the policy directives that influence institutional actions.
- To conduct a literature review of individual differences and determine the relation to academic success and performance indicators to determine indicators of academic achievement in the first-year fundamental Science modules.
- To evaluate the predictive value of available attributes and performance indicators to determine indicators of academic achievement in the first-year fundamental Science modules.

### 1.3.2 Research objectives

The following research objectives were pursued in this study:

- To examine admission practices and enrolment management models in other institutions (also internationally).
- To investigate the status of Mathematics and Science education at school level, Grade 12-results and its impact on first-year students at university.
- To investigate general academic proficiency and its relationship with academic performance.
- To examine the importance of mental processing in Mathematics and Science for academic achievement.
- To identify non-cognitive indicators and attributes (i.e. personality, motivation, teaching and learning, and anxiety) that contribute towards academic success at first-year level,

with specific reference to the fundamental Sciences (Mathematics, Physics and Chemistry).

- To examine the relation between biographical variables (i.e. gender, age, ethnicity, home language) and first-year performance in fundamental Science modules.
- To examine the predictive value of school performance (i.e. total Grade 12-score), with regard to success in first-year fundamental Science modules.
- To correlate school performance in individual subjects (i.e. Grade 12 Mathematics, Physical Science and English) with first-year performance in fundamental Science modules.
- To examine the predictive value of an independent scholastic aptitude test, namely the Stellenbosch University Access Test, with regard to success in first-year fundamental Science modules.
- To examine the predictive value of personality traits, as measured by the Basic Traits Inventory (BTI) as well as the Study Orientation in Mathematics Tertiary (SOMT), as measured by this inventory, with regard to success in first-year fundamental Science modules.
- To decide on influences as theoretical base for understanding student academic achievement.
- To combine the identified indicators to craft a conceptual framework for placement.
- To make recommendations emanating from the results and deductions that can be practically implemented in enrolment management in institutional policy and processes.

## 1.4 RATIONALE OF THE STUDY

There are seven reasons that underline the importance of this study:

- Firstly, the greater emphasis that education authorities place on institutional efficiency and student academic success needs further investigation.
- Secondly, the policy directives, forcing changes that impact on Higher Education institutions (mergers and funding) for the 21$^{st}$ century, specifically in the South African Higher Education sector.
- Thirdly, the poor academic achievement of first-year Science students, indicating the growing 'gap' between school and university content, academic literacy (reading and writing) and life skills.

- Fourthly, the increase in student enrolment in Higher Education, creating a need for authentic and valid predictors of academic success within the diverse cultural and linguistic South African context.
- Fifthly, the little research performed regarding the school system on the impact of the National Curriculum Statement, providing students to Higher Education, from 2009.
- The sixth reason concerns the relatively low number of students studying in the fundamental Sciences (Mathematics, Chemistry and Physics) and even fewer continuing to become teachers in these disciplines.
- Finally, the lack of an existing theoretical framework for optimal and appropriate placement in complex settings, where students have diverse backgrounds and levels of academic preparedness (especially in Science and Mathematics-related fields) necessitating research. All South African universities are facing the same challenges, and a framework could assist in directing students to more suitable streams for their own profiles and assist with "access for success".

## 1.5 CONCEPTS AND ASSUMPTIONS RELEVANT TO THIS STUDY

The working definitions, clarifications and theoretical, methodological and meta-theoretical assumptions below were applied in this study to ensure a shared understanding and meaning of the core concepts used.

### 1.5.1 Theoretical assumptions (working definitions of key concepts)

*1.5.1.1 Student performance*

Student performance is an indication of the degree of achievement of a student in the first year of university study and can be applied at three different levels:

- Firstly, student performance reflects performance (a percentage) in one particular module (i.e. Mathematics 1A).
- Secondly, performance can indicate 'pass' or 'fail' across all the registered modules for the specific student (i.e. passing Mathematics, Physics, Chemistry, and only failing Geology, will indicate a 75% pass rate).
- Thirdly, performance can indicate the period of time a student used to complete the qualification and graduate (i.e. four years for the completion of a three-year BSc-degree).

In this investigation, all three of the above will be applied, depending on the specific research question and analytical techniques employed.

#### *1.5.1.2 Throughput*

Throughput indicates the number of successful students per programme passing the module or programme, in relation to the number that initially registered at the beginning of the period of study (e.g. 56% throughput would indicate that 56 out of every 100 students who were registered at the beginning of the semester or of the cohort, passed).

#### *1.5.1.3 'Drop-out'*

'Drop-out' rate indicates the students who terminated their studies without completing the module, semester or programme. The reasons for drop-out could be poor performance (failing), financial or personal reasons (e.g. 35% drop-out would mean that of every 100 students who registered, 35 either failed or terminated their studies).

#### *1.5.1.4 Placement*

Different models of student admission and selection are applied at South African universities. In this study, the challenge to perform responsible placement of students after admission is therefore investigated for Science programmes. Placement of students is a process of accommodating students with a broad range of academic preparedness competencies and skills for post-school study and involves placing every student in a programme or stream where his/her student profile best matches the performance profile of the specific academic programme. Thus, students will firstly be admitted, based on general programme-specific admission criteria and, should then be placed in a suitable programme or stream of the required qualification after assessment.

Previous research on selection and admission testing mainly with privileged students from historically advantaged schools focused on predictors of academic success. For example, literature from Huysamen and Raubenheimer (1999:132-138), University of Cape Town (MSEP 2005) and Rademeyer and Schepers (1998:33-40), identify individual differences among students with regard to aspects such as vocabulary, reading ability, comprehension, calculation, numeric ability, learning potential and study orientation as being important indicators of academic success.

#### *1.5.1.5 Framework*

In this study, a framework refers to a conceptual pattern or structure, based on foundational principles derived from theoretical and empirical findings and deductions, as applied in the

Higher Education sector. This framework will serve as a point of departure for placement of first-year students in Science programmes (De Bruin 2000:21 and Gous 2002:13-25).

#### *1.5.1.6 Science programmes*

In the context of this study, Science is utilised as the overarching field that includes fundamental fields such as Mathematics, Physics, Chemistry and Geography. Science is applicable in many contexts e.g. in Political Science, Information Science and Psychology. For this study however, the term Science will include Natural Sciences, Agricultural Science, Engineering, Information Technology, Environmental Science, Technology, Health Sciences and other related Science disciplines. All aforementioned Science disciplines (and many others not mentioned) depend primarily on school performance in Mathematics and Physical Science, for admission purposes.

#### *1.5.1.7 First-year students*

In this study, first-year students refer to students progressing from the school system into a Science programme in Higher Education, i.e. first-time entering students into Science modules. Results of the overall performance in specific first-year modules reported on in this study will reflect on all the students registered in the module (including students repeating the module or transferring from other programmes).

#### *1.5.1.8 Individual differences*

Every human being is born with common human attributes (cf. species development described by Scarr 1992:1) but also possesses individual variations. These variations are created by genes and environmental influences and include personality, social, intellectual and physical development. With reference to this research, individual differences implicate any individual differences influencing academic performance. However, studies of the role of individual differences in academic performance have often been fragmented. In this study, it was anticipated that useful indicators shown to be relevant from previous studies would be identified, as well as new authentic predictors that will be more suitable for the current South African Higher Education environment.

### 1.5.2 Methodological assumptions

An inquiring mind seeks to inquire into a particular phenomenon. Research then follows a systematic approach to understand the phenomenon and make valid inferences (Gous 2002:25). According to Mouton and Marais (1992:40), five dimensions showed are described when typifying the empirical research design, namely:

- *unit of analysis*: a specification of the subjects/objects/artefacts that have been studied;
- *dimension of time*: whether the study was conducted at a certain point in time or over an extended period of time;
- *research method*: the method refers to the purpose of the research and whether it is descriptive, explanatory, evaluative or exploratory by nature;
- *research strategy*: the strategy refers to the universal or contextual nature of the empirical investigation; and
- *method of measurement*: the method of data analysis, being either broadly quantitative or qualitative, or leading to various variations of the two methods.

#### *1.5.2.1 Unit of analysis*

In this investigation, the following units of analysis were applicable:

- *Individual students*: students registering as first-year students at a university in South African.
- *Groups of students*: cohorts of first-year students enrolled in various programmes in Natural Sciences, Engineering or Health Sciences at a university.
- *Modules* in first-year programmes forming part of the curriculum.
- *Social artefacts*: content and environmental conditions of education at university level, with special reference to first-year modules.

#### *1.5.2.2 The dimension of time*

This study investigated the progression of students from school, through the first part of the first year, and forms part of a series of *cross-sectional* research. The fact that students were required to complete tests and surveys at a given point in time (e.g. at the beginning of the first year) also placed part of the investigation in the cross-sectional category.

#### *1.5.2.3 Research method*

The research method relates to the research goals the researcher would like to achieve via exploration, and descriptive, causal, explanatory, evaluative or predictive measurement (as described by Mouton 2003:53-54). Empirical research can be scrutinised in the aforementioned categories. This investigation can be typified as descriptive, exploratory and predicative in nature:

- The *descriptive nature of the research* represents an attempt to describe phenomena in detail. For example, recording of student results after school and at university level, and the incorporation of the literature review on Higher Education policies and procedures.

Describing general cognitive ability; science education; and non-cognitive influences on academic achievement, and relating these to the abilities, traits and behavior of the students, portrays the descriptive nature of the empirical investigation.

- The *exploratory nature of the research* represents exploration of the relatively unknown results of the new school-leaving curriculum (the National Curriculum Statement). The development and consequences of the concept 'placement' (as a relatively unknown research area) also reflect elements of exploratory research.
- The *predictive nature of the research* represents the prediction of academic success, given student profiles, school competencies and attributes in South African Higher Education.

#### *1.5.2.4 The research strategy*

The research strategy represents a choice between two approaches, as identified by Mouton and Marais (1992:48), to be either:

- *Contextual*, where events or phenomena are studied in terms of immediate context. This investigation focuses on the academic achievement of first-year students in Science programmes at mainly one specific institution and is therefore highly contextual. The implication might be that the findings and conclusions cannot necessarily be generalised for all South African institutions, but it is highly likely that some of the results will be applicable.
- *General*, where phenomena are studied as representing a larger population. The fact that the national response to first-year performance is of unanimous concern could imply that this study might influence the vast majority of first-year students in Science programmes in South African Higher Education institutions.

The research strategy applied in this study therefore represents a blend between the two approaches, namely contextual and general. This empirical investigation focused on the placement of students in specific programmes at a specific institution (University of Johannesburg), and is therefore highly contextual but should also hold theoretical and practical implications that transcend the immediate contextual boundaries of the study. Hence, it is hoped that the proposed study will not only provide solutions to an immediate local problem, but also contribute to the development of a general framework that may serve to guide research and practice across faculties or institutions.

#### *1.5.2.5 Method of measurement*

The method of measurement in this research is quantitative, since statistical concepts, procedures and analysis were used. The research is descriptive and predictive in nature and aim at gathering accurate information. Information was collected by means of various standardised and unstandardised instruments and processes.

### 1.5.3 Meta-theoretical assumptions

In any research, there will be assumptions underlying certain theories that will not be tested in the investigation (Mouton and Marais 1992:198), such as meta-theoretical assumptions. Meta-theoretical assumptions are underlying the theories that determined the context of this study. The following sub-disciplines in the fields of teaching and learning, psychology, as well as Science disciplines have been investigated:

(i) Teaching and learning
(ii) Cognitive ability
(iii) Personality
(iv) Mathematics
(v) Chemistry
(vi) Physics

The following models and approaches of the abovementioned sub-disciplines have been scrutinised:

(i) The student-flow model for Enrolment Management
(ii) The Three Stratum Model of mental abilities
(iii) The revised Bloom's Taxonomy of cognitive levels
(iv) The cycle of modelling in Mathematics
(v) The trait approach to personality
(vi) A multi-cultural approach to personality
(vii) The constructivist approach to learning.

## 1.6 RESEARCH METHOD

This investigation can firstly be typified as a contextual, descriptive and predictive study of academic performance in the first-year of university study in fundamental Sciences (Mouton 2003:53-54). The explorative and predictive nature of the research is also applied, in order to develop a framework for placement of first-year students in Science and related programmes (cf. Sections 1.5.2).

The study aims to consolidate different components that impact on the placement of students (i.e. role of individual differences in academic ability, personality attributes, and study orientations and attitudes) into an integrated framework that should enhance placement of first-year students in Science programmes. Furthermore, the study aims to stimulate further research on academic success of first-years in general, specifically in Science programmes.

The research progresses in four phases:

- The initial phase for developing of a framework is exploratory and focuses on a review of the relevant existing literature on the changing South African Higher Education landscape (cf. Chapter 2), and individual differences of students (cf. Chapter 3 and 4). The review also assists in identifying variables applicable to this study.
- The second phase is the description of related principles and assumptions, as well as the components of the learning community (teaching and learning culture, student profiles and the institution). The role of the prevailing socio-political climate and from government directives with regard to Higher Education are taken into account for the institutional profile. The explanation of concepts such as deductions, foundational principles, guidelines and conditions contextualise the research (cf. Section 7.3).
- The explanation phase of the research served to highlight possible causal links between variables or events and explained the phenomena of interest. Data were collected by means of literature reviews, psychometric test results, school and university results and case studies of student placement (cf. Chapter 6).
- Finally, the impact and application of the framework are currently being tested and evaluated within the institution, as well as conducting an assessment of the effectiveness of given practices (Mouton 2003:37).

This study follows a quantitative approach, focusing on identifying variables that may be used to indicate first-year success in Science modules at university level. This approach is based on classifying and counting features, and constructing statistical frameworks in an attempt to explain what had been observed (Heppner & Heppner 2004:108). The type of research paradigm selected for this study is mainly post-positivist, with the following characteristics (Heppner & Heppner 2004:143):

- *Ontology* (the nature of reality): critical realism with the (real) reality only imperfectly and probabilistically apprehendable.

- *Epistemology* (the relationship between the inquirer and the known): modified dualist/objectivist; critical traditional/community findings probably true.
- *Methodology* (the methods of gaining knowledge of the world): modified experimental/manipulative; critical multiplism; falsification of hypotheses and may include qualitative methods.

The approach is typified as post-positivist, presuming that an external reality (“the real world”) exists, independent from the researcher. The aim of the research is to design models to enable scientists and practitioners to better understand the world in which they operate. The models will integrate the variables of interest into frameworks. The post-positivist view does not aim to develop theories, models and frameworks that reflect absolute truths about reality, but rather useful frameworks, models and theories that can be expected to generate new research and allow predictions that conform to empirical observation.

## 1.7 DEMARCATION

The geographic area demarcated for this investigation is the University of Johannesburg, Gauteng, South Africa. The University of Johannesburg (UJ) is a new institution (post-mergers) and offers comprehensive academic programmes (diplomas and degrees). The university has 48 000 students and four campuses across this African city. The results found in this study will transcend the boundaries of the University of Johannesburg and may be made applicable to other emanating situations.

This particular study also falls within the field of Higher Education Studies. Tight (2003:7) categorised eight key themes in Higher Education. This particular investigation clearly has a key interest in “The student experience” category of Tight (2003:7). This category includes access to Higher Education, success and non-completion, as well as the experience of different student groups. This investigation focuses on access and first-year success, but also probes quality, and institutional management, with an emphasis on enrolment and system policy.

In a recent investigation into Higher Education, Bitzer and Wilkinson (Bitzer 2009:369-400) added two additional topics to the eight themes identified by Tight (2003:7). The two additional topics are authentic to the diverse South African context and are: a) Higher Education transformation in South Africa and b) Higher Education and socio-cultural links/relationships/responsibilities.

Mapping this particular research in the field of Higher Education "…matters much to both a country as a whole and to each citizen." Furthermore, this study manifest "…a field of interest for most who work in it…" and "…include publishing to position the professional roles of practitioners" as explained by Bitzer and Wilkinson (Bitzer 2009:369-400).

## 1.8 THESIS STRUCTURE

In chapter two, a comprehensive literature study of the changing South African Higher Education sector is provided. Relevant policies that may direct student academic success are analysed. Directives of institutional reactions stemming from the policies and indicating towards academic success and Science learning programmes are also identified. In contextualising student success, the management of enrolment, quality in Higher Education and the significance for Science learning programmes are investigated. Increased government subsidies for Sciences, accompanied by the diminishing pool of potential Science students are said to direct the importance of success for studies in Science programmes. It seems evident that Higher Education changes impact on the entire Higher Education sector, and that institutions react with appropriate strategies and procedures.

In chapter three, the focus turns towards the individual differences in first-year students' cognitive abilities. This chapter probes general mental ability and academic achievement. The Three Stratum model is investigated to provide structure to the complexity of general mental ability. The application of mental ability in knowledge acquisition is described in terms of Bloom's taxonomy, with an emphasis on higher-order thinking required for study in Science and Mathematics. The importance of Mathematics and Science as disciplines is investigated and an evaluation of school conditions and teacher quality is provided.

In chapter four, a further probe into individual student differences is performed. The role of non-cognitive individual differences in academic achievement is investigated, including the influence of personality traits, confidence, motivation and interest on performance. The influence of deep learning, mathematical anxiety, self-efficacy, cultural differences and locus of control is also investigated.

In chapter five, the research design and methodology are contextualized with reference to the research problem and objectives. The empirical investigation and collection of data, use of statistical concepts, procedures and analyses are discussed in detail.

In chapter six, the results of the empirical research are reflected. The statistical correlations and predictability of the biographical profile; Grade 12-results; Access Test results; and personality profiles with Chemistry, Physics and Mathematics achievement at first-year level are discussed. A variety of quantitative statistical techniques (chi-square, ANOVA, Kruskal-Wallis and hierarchical multiple regression) are applied to present and interpret the data of this investigation.

In chapter seven, the deductions from results are drawn into foundational principles to inform the development of a framework for placement. The framework for placement of first-year students in Science programmes is presented as a conceptual structure with components such as foundational principles, guidelines and conditions for the implementation of enabling placement.

The final chapter provides a brief discussion on the context of the study. The limitations and recommendations for further research with the practical implications of the study concludes this investigation.

This study uses a technique that is a preferable teaching tool in Physics and Chemistry namely to represent the problem schematically. In every chapter, the flow of the content is indicated by means of diagrams to emphasise the course of flow and keep the reader abreast. Figures are used to consolidate ideas, and metaphors from the disciplines (Mathematics, Physics and Chemistry) are applied to simplify inter-disciplinary similarities, and differences are demonstrated visually.

## 1.9 SYNTHESIS

The overall research problem of the proposed study was to establish a framework for the optimal placement of university students in Science programmes. It is hoped that the resulting framework will promote academic success in Science programmes. As outlined in the research rationale, there is a definite need for a framework that will serve as a 'road map' for the placement of university students in Science programmes. Thus far, the current lack of such a placement framework has inhibited research on the admission, selection and placement of prospective students.

# CHAPTER 2

## *THE CHANGING SOUTH AFRICAN HIGHER EDUCATION LANDSCAPE: CHALLENGES AND OPPORTUNITIES*

## 2.1 INTRODUCTION

The South African Higher Education landscape changed continuously over the past sixteen years. A number of resulting challenges gives rise to the rationale underlying this study. Figure 2.1 provides an outline of this chapter. Within the arrow-shaped diagram, four sections are identified that will have implications for Science learning programmes in the South African Higher Education sector, namely changing Higher Education policies, enrolment management, quality enhancement of learning programmes in general, and Science learning programmes specifically.

The discussion commences with a review of a selection of national policies that have directed South African Higher Education since 1994. Figure 2.1 indicates the flow of the chapter and simultaneously presents a model of the various aspects that will explain student academic achievement.

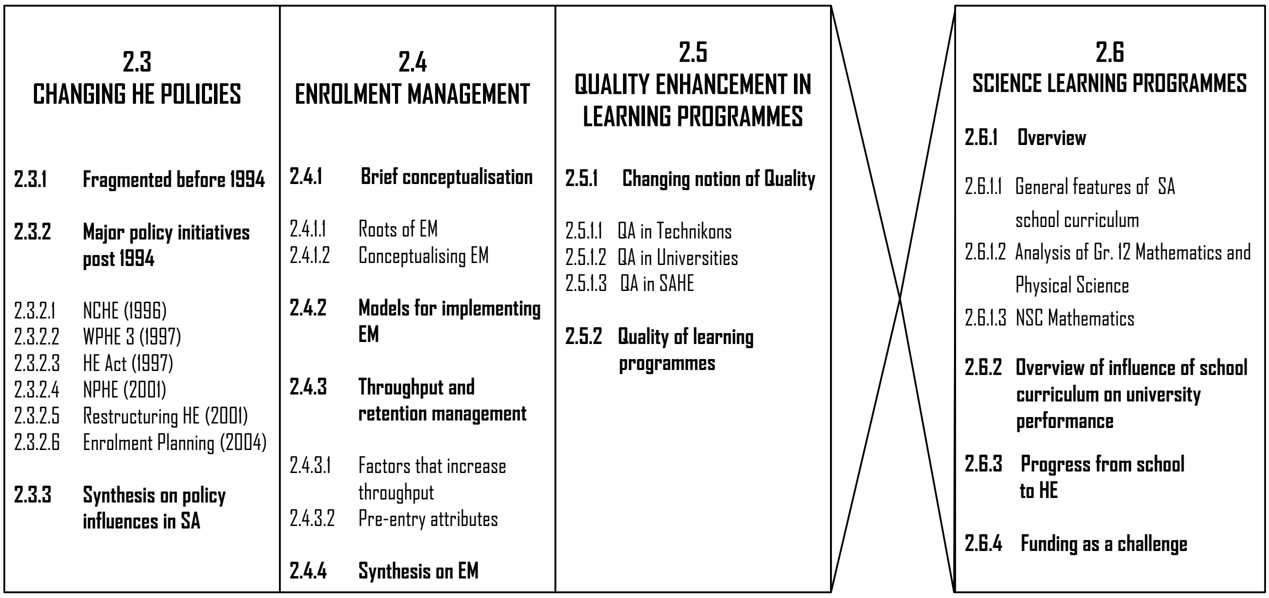


***Figure 2.1*** **The challenges and responses from the changing SA HE landscape**

## 2.2 RATIONALE UNDERLYING THIS CHAPTER

The Higher Education enterprise in South Africa experienced constant change since 1994. These changes challenge practitioners to review practices, rethink procedures and develop new policies. The aforementioned proposals (cf. Section 2.1) that give rise to and strengthen the rationale underlying this study result from this changing Higher Education landscape.

The first aim of this chapter is to identify, analyse, reflect on, prioritise and synthesise Higher Education challenges that have a direct or indirect impact on establishing an optimal student placement framework in Science programmes and fundamental modules. The second aim is to contextualise the above challenges, by focusing on available literature related to the enhancement of the academic success of undergraduate students, or the lack thereof.

Thirdly, further contextualisation of the abovementioned literature findings will be attempted. This elaboration of the theme will be done via a deliberation of relevant studies, research projects, papers, conference proceedings and articles geared at the academic success (or lack thereof) of students registered for fundamental Science learning programmes (and/or modules) at Higher Education Institutions (HEIs).

The Republic of South Africa (RSA) appointed its fourth post-apartheid Minister of Education in 2009. Since 1994 every term of the Ministry has been characterised by influential and far-reaching policy changes and revisions. Hay and Monnapula-Mapesela in Bitzer (2009:12) indicate the institution of massive transformation agendas. The unique policies of these Ministries have had (in most cases) significant implications for the Higher Education sector. The following discussion reviews and reflects on relevant policy-related changes in the South African Higher Education sector, that have significance for this study and/or the challenge of increased academic effectiveness (success) of students.

## 2.3 THE IMPACT OF CHANGING EDUCATION POLICIES ON THE SOUTH AFRICAN HIGHER EDUCATION LANDSCAPE

This section discusses six selected policies that impact on the governance and admission processes and procedures as well as management of students in Higher Education in South Africa. These policies are identified as major drivers in the sector and provide a framework for this research. In Figure 2.2, the outline for this section is presented.

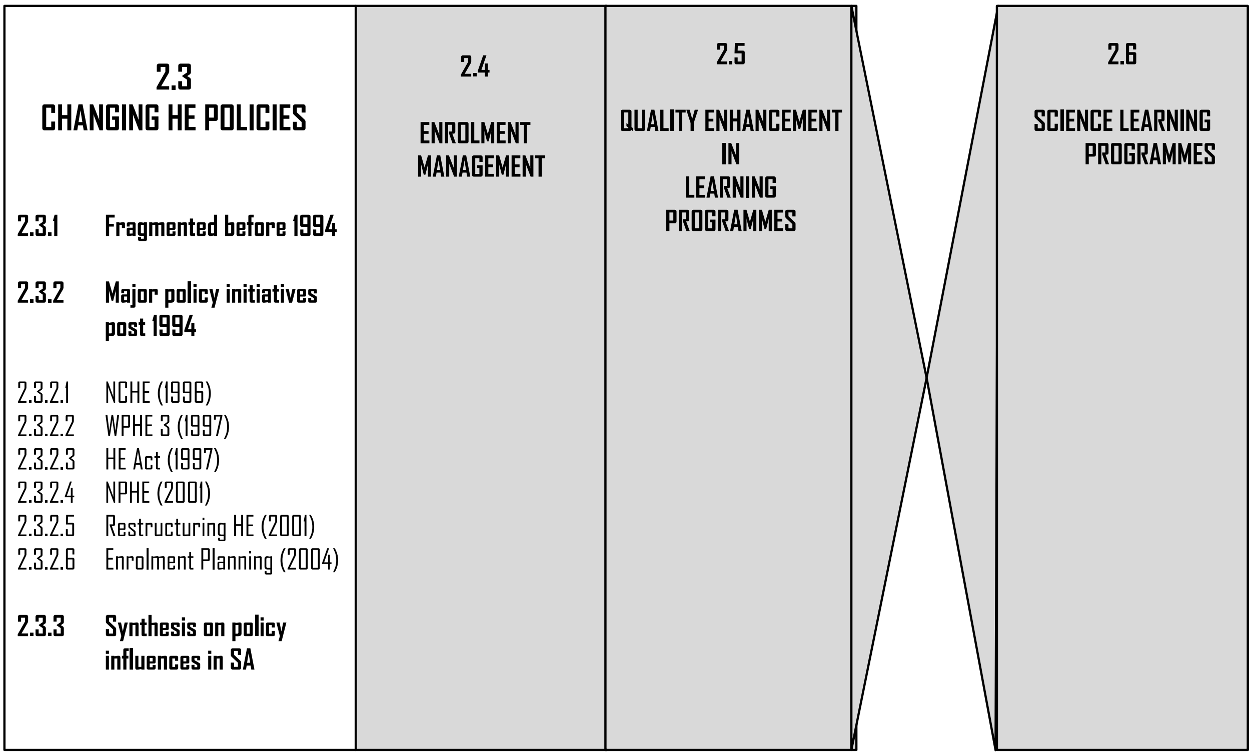


***Figure 2.2*** **Changing Higher Education policies in South Africa since 1994**

In the following analysis of policies, the progression from pre-1994, in investigating six policies and a synthesis of these policies, will be discussed.

### 2.3.1 A fragmented Higher Education system before 1994

The geo-political agenda of South African apartheid planners largely dictated the Higher Education sector from 1948 to 1994 (RSA DoE 1999). Racial inequalities in student access and success characterised the Higher Education system and were evident across academic disciplines and institutions. In the apartheid system White South Africans had more access to educational resources and opportunities than their Black, Coloured and Indian counterparts (Van Wyngaard & Kapp 2004:185). According to recognised Higher Education practitioners (cf. Habib & Parekh 2000:39-51; Hay & Fourie 2002:115-131), the previous Higher Education system was fragmented along provincial and racial lines.

Internationally, universities have been subjected to powerful forces of change for many years. The transition from elite to mass Higher Education provision, new Higher Education government relationships and penetration of the market, accompanied by increasing public and societal demands and expectations, are but some of these forces. In South Africa the apartheid era delayed these international trends. Colin Bundy (2006:3) states that in South Africa, Higher Education "…remained largely insulated from the global climate change prior to 1994." This fragmented South African Higher Education system consisted of eleven Historically White

Universities (HWUs), and ten Historically Disadvantaged Universities (HDUs). Some of the HDUs were located in the so-called “homelands” as independent universities in rural areas. Also contributing to the fragmentation, the Universities Extension Act (1959) allowed for the establishment of universities for Black communities “…whilst maintaining the apartheid divide” (Grobbelaar 2004:35).

The racial divide manifested in different universities for different ethnic groups: the Indian community was primarily served by the University of Durban-Westville (UDW), while Coloured students primarily attended the University of the Western-Cape (UWC). The traditional Black Higher Education institutions consisted of one university for each of the Zulu (University of Zululand), Xhosa (Fort Hare University) and Sotho (University of Limpopo) populations. There was also one medical university (Medical University of South Africa [MEDUNSA]) and a multi-campus university to provide Higher Education to urban Black communities (Vista University). Grobbelaar (2004:35) comments that these universities enjoyed considerable autonomy, because they received a block subsidy grant from the government, with hardly any limitations on expenditure.

The final example of fragmentation was the existence of 15 technikons, which provided specific vocational and professional programmes that fell outside the range of formalised academic and professional university programmes. Before 1993, technikons did not award degrees, which impeded post-graduate study for students. In 1993, legislation changed to enable these institutions to award BTech, MTech, and DTech degrees. The eight Historically White Technikons (HWT), together with the seven Historically Disadvantaged Technikons (HDT), shared a core curriculum for the National Diploma (ND) programmes and are currently known as Universities of Technology (UoTs).

Ian Bunting (2004a:37) explains the political ideology of the so-called binary divide between technikons and universities by identifying the essence of university programmes as *Science education,* with *Technology education* being the essence of technikon programmes. Bunting claims that the term *Science* designates “…all scholarly activities in which knowledge for the sake of knowledge are studied.” The term *technology* describes “activities concerned with the applications of knowledge.” This binary divide separated institutions legally, and little collaboration between universities and technikons took place. Universities could not involve themselves in the application of knowledge (technology) and rather focused on the development and training of basic scientists and researchers. Similarly, technikons did not involve themselves in the generation of new knowledge.

Against the background of the apartheid–induced binary divide, Grobbelaar (2004:37) concludes that "…the glaring inadequacies of the fragmented, racially divided system of independent institutions…" exposed five neglected, yet critical Higher Education areas that desperately and urgently needed attention, namely the:

i) inequitable distribution of student and staff access along race, gender, class and geographical dimensions;
ii) "chronic mismatch" between the outputs (from Higher Education) and the economy;
iii) inclination towards a programme-based approach;
iv) inadequate teaching and research context; and
v) lack of regulatory frameworks.

Radical changes in the South African Higher Education sector were introduced after the establishment of the democratic government in 1994. It began with the development and approval of various policies that were gradually implemented by the Higher Education sector.

The first post-apartheid term of the South African Government of National Unity in April 1994 brought about transformation at every level of society. The 1994 government, with a vision for "reconstruction and development", focused on the challenge of economical development, as well as social and political change. The transition to a democratic dispensation created high expectations for fundamental change within the Higher Education sector. The procedure to change processes was through policies, and therefore the following discussions will focus on six policy documents developed within the first ten years of democracy in South Africa.

### 2.3.2 Major policy initiatives in Higher Education in post-1994 South Africa

The above section concludes with five critical areas that require attention. In the view this, six major policies pertaining to changing the organisational culture of the Higher Education sector and specifically, South African universities, are examined. In 1996, the *National Commission on Higher Education* (NCHE 1996a) (cf. Section 2.3.2.1) published a report and, in the following year, the *White Paper on Higher Education transformation* (RSA DoE 1997a) (cf. Section 2.3.2.2), as well as the *National Education Act* (RSA DoE 1997b) (cf. Section 2.3.2.3) were formalised. In 2000, the document *Proposals for Restructuring* was tabled, and in 2001 the *National Plan on Higher Education* (RSA DoE 2001) (cf. Section 2.3.2.4) and the document *Restructuring of the Higher Education system* (RSA DoE 2002b) (cf. Section 2.3.2.5) directed the future of this sector. To conclude this selection, the 2004 publication of *Student Enrolment Planning in Public Higher Education* (RSA DoE 2004a) (cf. Section 2.3.2.5) will be discussed.

Before the appointment of the Minister of Education in 1994, the democratic government tasked a commission to analyse the then current national Higher Education context and to make recommendations. This first major step taken by the Minister to reform Higher Education, took place with the appointment of Mr. Jairam Reddy as chair of the National Commission on Higher Education in 1995.

*2.3.2.1 The National Commission on Higher Education (NCHE) report (1996)*

The National Commission on Higher Education (NCHE 1996) conducted a groundbreaking investigation, with a direct and long-lasting impact on subsequent policy deliberations. Recommendations made by the Commission made in the final chapter of its report had the potential to change the entire national Higher Education sector. The following NCHE recommendations (and identified challenges) are most pertinent within the context of this study:

- "Successful policy must overcome a historically determined pattern of fragmentation, inequality and inefficiency" (NCHE 1996:5). Increased participation (of the whole South African population) will expand the basis for access to Higher Education and accommodate a larger and more diverse student population. Widening access should also address the shortage of students in the Sciences and related disciplines.
- "Successful policy must restructure the Higher Education system and its institutions to meet the needs of an increasingly technologically-oriented economy" (NCHE 1996:7). Greater responsiveness to the needs and interests of society will produce graduates who are better prepared for the labour market after successful completion of Higher Education qualifications.
- "Successful policy must reconceptualise the relationship between Higher Education and the state, civil society and stakeholders, and among institutions" (NCHE 1996:9). Increased cooperation and partnerships should therefore involve all parties to enhance the alignment of the Higher Education system in preparation for societal needs.
- Furthermore, the NCHE-report advocates a single and simplified Higher Education system (NCHE 1996:2).

In view of the preceding, a number challenges flowing from the NCHE report will be discussed, followed by an investigation into the relevance of the report.

a. Challenges from the NCHE report

The following are the most relevant challenges resulting from the report:

- The equalisation of the various pre-1994 systems must be presented clearly and be well planned. In practice, it will probably take more than one generation to counter stereotyped effects in full. Nearly fifty years of incoherent and parallel practices will not disintegrate entirely with the appearance of a policy declaration. Most of the current staff in the educational sector has well embedded practices and mind frames grounded in the previous fragmented system. This is evident in the provision of first-year students to Higher Education by the school system.

- The NCHE-report adopts the concept of "cooperative governance" between the state and civil society (Cloete 2004:54). The government and public domain find "…themselves in a relationship of functional interdependence…", and this relationship is moving away from the traditional opposing each other, to negotiation for cooperation. Cooperation is based on the principles of equity, academic freedom, quality and institutional autonomy, as well as democratisation, effectiveness and efficiency. However, according to the NCHE (1996:57-60), the Commission issued a warning that the state should maintain the leadership role in the partnership. The international trend, where government becomes a powerful partner, involving other institutions, agents and bodies in governing Higher Education, is also redefining and reconfiguring the state, and mediates state intervention and institutional autonomy.
- This relationship between the steering role of the state and the self-regulatory role of universities is positioning strategies to aspire to the noble principles of 'equity', 'effectiveness' and 'efficiency' via these practices. Institutions are striving for institutional quality (cf. Section 2.5) to align these principles with their 'new' practices of teaching and research, for example, by taking into account that such 'new' mechanisms will serve as indicators of academic success. Academic success for all students (the wider community) will consequently influence the academic success of students in Sciences.

b. Relevance of the NCHE report

The NCHE report identifies three central attributes to unify the new Higher Education sector in South Africa, namely increasing participation, greater responsiveness, and increasing cooperation and partnerships. The significance emanating from this report (within the context of this study) pertains to:

i) equitable institutional practices involving all potential Higher Education students (taking into consideration that institutional strategies were, for many years, applied in an inconsistent and rather differentiated manner)
ii) increasing student numbers (with particular reference to specific scarce skills areas)
iii) the gradual increase of academic/study effectiveness and efficiency of all Higher Education students.

The above directives point towards aspects such as scientific planning and implementation of the widening of Higher Education participation, an increase in student numbers, and a much broader distribution of social student groups and classes (cf. Section 2.4). Furthermore, the coordinated increase of enrolment will combine with academic success specifically in the Science, Engineering and Technology (SET) learning programme areas (cf. Section 2.6).

This report also projects an increase in public Higher Education student enrolment. In 1995, approximately 800 000 students were enrolled in institutions, and the NCHE (1996) expected 1.5 million students to enrol in 2005. This expectation was not realised – the total number of students who were enrolled for public Higher Education in 2005 was only 743 000. It should be borne in mind that the 'capping' of student numbers (cf. Section 2.3.2) was probably instrumental in the lack of growth. However, the three abovementioned recommendations undoubtedly challenged Higher Education admission and student support practices.

In an evaluation of the NCHE report, Bundy (2006:12) found that substantial growth in the participation of Black students (and Black academic staff) in Higher Education has materialised since 1996. The above paragraph indicates a decrease in total participation (from 800 000 to 743 000). However, whereas in 1993, only 12% of the South African Higher Education population comprised Black students (NCHE 1996:64), this number increased sharply to 59% in 1999, 65% in 2002, decreasing slightly to 63% in 2006. Furthermore, the majority of new Black students enrolled at historically White campuses. The growth in Black student participation also introduced complications with retention and progress. Bundy (2006:12) notes that "…access gains also prove less healthy when measured against student success levels. A 'wasteful' number of enrolled students fail to complete their studies, there is a decline in retention rates, and dropout rates are as high as one out of five."

Based on the report of the National Commission on Higher Education in 1996, three different versions of the National White Paper, "A Programme for the Transformation of Higher Education", was released for public comment in March 1997.

#### *2.3.2.2 The White Paper 3 on Higher Education Transformation (1997)*

The White Paper 3 on Higher Education Transformation (WPHE), published by the Department of Education (RSA DoE 1997a) in August 1997, provides further impetus to the achievement of a uniform national Higher Education system. The social broadening of the Higher Education sector (in terms of race, class, gender and age) is placed at the forefront. As in the case of the NCHE report, the WPHE urges the Higher Education sector to optimally accommodate a diverse student population. Increased student participation in Higher Education (from all the aforementioned social and racial classes) is considered to be a necessary requirement for the transformation of Higher Education, the latter being key to the social, cultural, and economical development of the country.

The subsequent challenges and relevance of the WPHE will now be discussed.

a. Recommendations from the WPHE

The WPHE (RSA DoE 1997a:8-10) explicitly expresses a future vision for South Africa's Higher Education system, with the following being some of the essential and most desirable elements of this vision:

- Increased democratisation of Higher Education institutions (cf. Section 2.3.2.1), which refers to increased and broadened participation (and provision) of Black, female, disabled and adult students.
- The quest for a balanced and societal-driven effort towards the creation, acquisition and application of Higher Education knowledge.
- Increased development of the country's human capital, especially provision of lifelong learning opportunities.

b. Challenges arising from the WPHE

The WPHE (RSA DoE 1997a:8-10) also expresses the following challenges:

- The increase in student participation poses challenges to curricula (and programmes) and initiates increasingly flexible models of teaching and learning to accommodate a diverse and larger than before student population. This emphasises responsible access and proven mechanisms of academic development and support for students, geared towards optimal academic success.
- Research should preferably be driven by societal needs and trends. Balancing research and discovery with specific societal needs will challenge the Higher Education sector. Research known to be embedded in scholarship should present direct societal application. The responsiveness to societal needs of increased technological economy will drive Higher Education to produce the requisite research, highly trained manpower and the knowledge to fulfil national needs. Research on the changing curriculum will be evident of the competitive global context of modern Higher Education.
- Among others, life long learning refers to continued learner facilitation, support and encouragement prior to studies via suitable identification, profiling, selection and placement. During the study period there should be continuous support, development, enrolment management (cf. Section 2.4), and work-based learning experience (where applicable). Upon completion of studies, feedback should be gathered from alumni and employers. This should inform the creation of opportunities for lifelong learning (such as

short learning programmes, invitations to enrichment programmes, flexible learning via the Web, and the availability of bursaries and scholarships). The above initiatives will create an enabling institutional environment where the culture will be sensitive to diversity, promote respect for human life and protect the individual against unfair behaviour and rejection.

The aforementioned recommendations and challenges are pertinent and appropriate to the context of this study. It addresses the dire need for qualified students in the scarce fields of Science and related disciplines, as well as the "efficiency and globalisation of the knowledge economy" (Bundy 2006:17). The NCHE therefore began by promulgating change, the WPHE exposed the direction of flow and finally, Parliament formally steered the sector with the Higher Education Act in 1997.

#### *2.3.2.3 The Higher Education Act (Act 101 of 1997)*

The WPHE (RSA DoE 1997a) preceded and culminated the Higher Education Act in 1997, underpinning transformation at a national level. The proposed restructuring of the Higher Education landscape required this legislation to drive the change. The following broad implications resulted from the Act:

- Firstly, the Act gave the Minister far-reaching powers to enforce, implement and (after consultation with the "to be established Council on Higher Education") change the Higher Education structure. This authority increased government control and gave a brand-new and unexpected meaning to the original desirable notion of cooperative governance.
- Secondly, this Act (RSA DoE 1997b:5) redefined Higher Education to encompass "…all learning programmes leading to qualifications higher than Grade 12…", and conceptually changed Higher Education from a discipline-based to a programme-based dispensation.
- Thirdly, the Act casually pre-empted the possible restructuring of the Higher Education landscape (which resulted in the mergers of several Higher Education institutions a few years later), while the interconnected nature of planning, governance and funding also received prominence. According to the Act (RSA DoE 1997b:12), the Minister may, after consulting the Council on Higher Education (CHE) and by notice in the Gazette, "…merge two or more public Higher Education institutions into a single public Higher Education institution."

The White Paper and the Higher Education Act prompted a national investigation into the size and shape of universities and culminated in a report entitled "Towards a New Higher Education Landscape: Meeting the Equity, Quality and Social Development Imperatives of South Africa in the 21$^{st}$ Century", published by the CHE in June 2000. This report made several proposals on the reconfiguration of Higher Education, with one of the proposals addressing the efficiency of institutions (cf. Section 2.5) by monitoring and increasing student throughput (and thus graduate output). This would be performed in conjunction with numerous institutional (as well as national) planning mechanisms and strategies (among others, student enrolment management and sustainable institutional effectiveness measures).

The two challenges of the Higher Education Act (and subsequent CHE investigation into a new Higher Education landscape) that are probably most relevant to this study are:

i) the new programme-based definition of Higher Education (cf. Section 2.6) and
ii) striving towards greater effectiveness and efficiency of universities (with reference to the goals they set for themselves and the programmes they offer) (cf. Section 2.5).

The implication is that institutions are expected to provide successful and qualified students within an optimal period of time. These aspects enhance a national and institutional search for and an emphasis on the increasing academic success of specifically undergraduate students. The academic success becomes more pertinent in the scarce skills programmes in the fundamental Sciences, constituting the basis of most Science, Engineering and Health Science programmes.

The planning and implementation of 'new' policies were well guided by The Higher Education Act and the WPHE. The sector was obliged to react and implement transformation. Real hard decisions were made, and the National Plan on Higher Education followed in 2001.

*2.3.2.4 The National Plan on Higher Education (2001)*

The second democratic Ministry of Education took the bold step of revealing its vision of a transformed Higher Education sector via its National Plan for Higher Education (NPHE) (RSA DoE 2001) in 2001. This declaration proposed:

- less duplication of programmes;
- increased statutory power to subsidise programmes where a need was anticipated (cf. Section 2.6); and
- greater institutional efficiency and effectiveness (cf. Section 2.5).

In summary, four principles underpinned the NPHE, summarised by the researcher's self-generated acronym "READ":

i) **Research** promotion (**R**): To "retain current research strengths and to promote the kinds of research and other knowledge outputs required to meet national development needs…" (RSA DoE 2001:60).
ii) Increased **Equity** (**E**): To "…ensure that the student and staff profiles progressively reflect realities of South African society" (RSA DoE 2001:30). The NPHE specifically cautioned

against unacceptably low levels of enrolment of the Black students in SET programmes, which had to be addressed urgently.

iii) Increased **Access** linked to Success (**A**): To "increase the number of graduates through improving the efficiency of the Higher Education system …" (RSA DoE 2001:14).

iv) Promotion of **Diversity** in the Higher Education system by means of mission and programme differentiation (**D**): To "ensure diversity in the organisational form and institutional landscape of the Higher Education system through mission and programme differentiation" (RSA DoE 2001:36).

All four underpinning principles of the NPHE are particularly relevant to the context of this study. However, the principle of widened student access, which simultaneously links to increased student success, addresses the underlying rationale of the study succinctly. The following section will be devoted to an analysis of aspects mentioned in the NPHE that relate to this principle and thus to the motivation for this study.

In the NPHE (RSA DoE 2001:7), the emphasis on throughput of students (thereby promoting academic success) becomes evident. The following mechanisms were proposed to address the "implementation vacuum" in order to direct its purpose, namely:

- Regulating competition among institutions and linking funding narrowly to student enrolments (cf. Section 2.5). These processes require strategic planning, as from 2003, namely that Higher Education funding was linked to the approval of three-year rolling plans, and alignment administrative and management systems to the smooth and effective functioning of the institution.
- Institutional redress focused on access of specifically Black students in past policies, whereas the NPHE urged institutions to develop new directions and trajectories to support institutional missions and plans.
- Funds were earmarked to realise particular objectives such as access for poor students, supporting under-prepared students and building research capacity (NPHE 2001:10).

The NPHE took even bolder steps, and all institutions were obliged to address equity and diversity. Facilitating access and increasing the numbers of successful students while also increasing research outputs, was easier said than done. Resources were stretched and had to be consolidated. The restructuring of the Higher Education sector as a whole became a reality in 2001.

*2.3.2.5 Restructuring of the Higher Education system in South Africa (2001)*

The NPHE confronted administrators, staff and students in the Higher Education sector directly (Bundy 2006:20) and marked the end of "symbolic policy making". The urgency remained to

"…ensure diversity in the organisational form and institutional landscape" and to "build new institutional and organisational forms and new institutional identities…" (RSA DoE 2001:12). In the "*Call to Action*: *Mobilising citizens to build a South African Education*", the Minister of Education, Prof. Kader Asmal (July 1999), announced that the shape and size of the Higher Education system "…cannot be left to chance if we are to realise the vision of a rational, seamless Higher Education system…" (RSA DoE 1999). This urged the Minister to appoint a task team to "investigate the feasibility of reducing the number of institutions and establishing new institutional and organisational forms…".

The Call to Action was to review the Higher Education institutional landscape, consider collaboration with the CHE and re-examine the strategic plan for the sector (CHE 1999:12). The review of the "…educational needs of local communities and the nation at large in the 21st century…" would most probably result in mergers among some institutions. As an introduction to enrolment management, Asmal (1999:12) challenged institutions to set targets to "…progressively achieve greater representation of women and Black academic staff, as part of their institutional plans." The Minister invited the Higher Education sector "…to inform educational policy and practice…" with research, critical reflection and authentic innovation indicating evidence that they were on their way to the $21^{st}$ century.

In the report, entitled "*The restructuring of the Higher Education system in South Africa"* (RSA DoE 2001), the recommendation was made to reduce the existing 36 universities to 21, by implementing institutional incorporations, mergers and closures. A table by Bitzer, in Van Wyngaard and Kapp (2004:187), indicates the 'old' and 'new' envisaged Higher Education landscape (see Table 2.1 below):

**Table 2.1** ***The Higher Education Landscape Pre- and Post-Mergers***
(Adapted from Bitzer in Van Wyngaard and Kapp 2004:187)

| INSTITUTIONS | Number of institutions before amalgamations, incorporations, mergers and closures | Number of existing or envisaged institutions in 2003 |
|---|---|---|
| Technical colleges | 152 | 51 clusters |
| Colleges of Education | 94 | 0 |
| Nursing colleges | 35 | 17 |
| Agricultural colleges | 11 | 11 |
| Universities and technikons | 36 | 21 |

In Table 2.1 (above), the closure of all colleges of education has to be noted, as well as the reduction in the number of agricultural and nursing colleges and universities. It was proposed that technikons should become Universities of Technology (UoTs). In some instances, they merged with universities to form so-called comprehensive universities. The funding of Higher Education institutions would also, as of 2003, be linked directly to the approved three-year "rolling" plans of Higher Education institutions, rather than to past student enrolment and success trends, as was done before. Rolling plans also needed to include programme-specific predicted student enrolments and throughput for a specific period of time. Higher Education institutions were obliged to manage the above aspects in a responsible and transparent manner (cf. Section 2.4.3).

The mergers influenced Higher Education programme offerings via the closure of colleges of education and incorporation of these into universities. This occurred in a time of a shortage of teachers in Mathematics and Physical Science and was of great concern (cf. Section 3.3.1). Furthermore, two mergers of universities with technikons brought about universities with wider than before programme offerings (known as "Comprehensive Universities"). The establishment of a 'new' type of Higher Education institution presented significant challenges to their management structures. This placed a major responsibility on academic managers (deans, heads of department and programme leaders). For the first time, students could be placed in a wide range of programme offerings which provided new options and choices.

The Minister merged three universities with two technikons, respectively. Firstly, the Port Elizabeth campus of Vista University, the University of Port Elizabeth and the Port Elizabeth Technikon were merged to form the Nelson Mandela Metropolitan University (NMMU) in Port Elizabeth, Eastern Cape. Secondly, in the central Gauteng region the Technikon Witwatersrand, the Rand Afrikaans University, and the two Vista University campuses in Soweto and on the East Rand respectively merged to form the University of Johannesburg (UJ).

According to Auf der Heyde (2004:1), the 'comprehensiveness' concept became the theme of much speculation and concern. Initially, the concern arose because the use of the term suggested a return to the conceptual streaming of Higher Education into several tiers, as had been proposed by the CHE earlier (cf. 2.3.2.3). This introduced the term 'comprehensiveness' into the debate on Higher Education restructuring, together with the term 'extensive' university. The concept 'comprehensive' was not used in an attempt to describe an institution that was somehow pedagogically or organisationally different from a university or a technikon. Auf der Heyde (2004:1) argues that the concept "comprehensive" was used for the simple reason that the DoE could not think of an appropriate name for an institution emerging from a university and a technikon.

For the purpose of this study, the term 'comprehensive' will describe the range of programme offerings, from certificates and diplomas (traditionally technikons offerings), as well as degrees up to doctorate programmes (university type qualifications), within one institution. The placement and guidance of students in a comprehensive institution introduced significant challenges that will be discussed subsequently.

#### *2.3.2.6 Student Enrolment Planning in Public Higher Education (2004)*

The central premise underpinning the five national policies (and/or projects or reports) deliberated in the preceding sections (2.2.2.1 to 2.2.2.5) is that the Higher Education system "…must be planned, governed and funded as a single national coordinated system" (RSA DoE 2004:2). The student enrolment planning document (2004:2) emphasises planning, whereby size and shape will pre-determine the national development agenda. Institutional planning "…in terms of access, redress and human resource development…" shifts the focus to strategic Higher Education management. The particular mention of "…uncoordinated institutional decisions on student enrolments and programme offerings…" indicates this change in practices. The national goals and priorities can be met by combining three crucial instruments, namely i) planning, ii) funding, and iii) quality assurance.

Enrolment planning in the South Africa Higher Education sector was officially introduced by the Ministerial Statement on Public Higher Education Funding (RSA DoE 2003a). The DoE began with a system-wide student enrolment planning exercise to facilitate implementation of the new funding formula. This would determine the number of students who would be funded according to government-approved goals and targets, as well as various projections. Institutional student input and output data for previous and future terms would inform funding formulae. The broadening of participation and access to Higher Education has since been widely discussed, and this research will hopefully contribute to the debate.

This enrolment planning documents (RSA DoE 2004b and 2004c) outline a framework informed by three key factors:

i) Matching of enrolment plans with available resources. Aforementioned impacts on expenditure frameworks of institutional management.
ii) Linking of the enrolment plans to national human resource and research priorities. The emphasis on scarce skills (Science and related fields) applies to this research.
iii) Enhancing quality, throughput and graduation rates. This includes the development of alternative programmes and support mechanisms in specific scarce skills areas mentioned.

Enrolment management of students and throughput highlight funding. What revenue do universities receive from government to operate? Governors at universities have been managing academic enrolments, based on the income students generate for an institution.

In Table 2.2, the difference in Classification of Educational Subject Matter (CESM) according to which funding takes place, is provided (RSA DoE 2004a and 2008a). Group 1 is the lowest subsidy category, with the subsequent weighting factor indicated in the columns to the right (per qualification type). The South Africa government subsidises every student (excluding private Higher Education institutions), and these institutions will be able to claim for every student upon successful completion of studies.

**Table 2.2** ***The Funding Grid for Teaching Inputs***
(Adapted from RSA DoE 2003a, RSA DoE 2004a and RSA DoE 2008a)

| Funding group | CESM categories included in funding group | Weighting factors for Teaching inputs | | | |
|---|---|---|---|---|---|
| | | Under-graduate | Honours | Masters | Doctoral |
| 1 | Education, Law, Librarianship, Psychology and Social Services | 1.0 | 2.0 | 3.0 | 4.0 |
| 2 | Business/Commerce, Communication, Computer Science, Languages, Religion, Philosophy and Social Sciences | 1.5 | 3.0 | 4.5 | 6.0 |
| 3 | Architecture, Engineering, Home Economics, Industrial Arts, Mathematical Sciences and Physical Education. | 2.5 | 5.0 | 7.5 | 10.0 |
| 4 | Agriculture, Fine & Performing Arts, Health Sciences, Life and Physical Sciences. | 3.5 | 7.0 | 10.5 | 14.0 |

According to Table 2.2, the subsidy for an undergraduate student in Law and Psychology (weight of 1) is less than for an undergraduate student in Health Sciences. If a hypothetical calculation were equated to the weighting of one (1) at R11 000 per annum (Lourens 2004), the following would be claimed upon successful completion of a programme:

| | | |
|---|---|---|
| Student A | a graduate in Law who has completed an LLB in four years | |
| | 1 (weight) x 4 years x R11 000 | = R44 000 |
| Student B | a honours student in Computer Science in one year | |
| | 3 (weight) x 1 year x R11 000 | = R33 000 |
| Student C | a doctoral student in Physical Sciences (teaching) | |
| | 14 (weight) x 2 years x R11 000 | = R308 000 |
| | [The research component should be added to the amount] | |

The funding formulae have been adjusted (teaching and research) in the past few years, but the principle remains. It costs more to train an architect, and therefore the subsidy will be higher. This amount is also only calculated, based on the minimum study years for any qualification. If it takes a student six years to complete a three year BSc, the number of years will still be multiplied by three, although the input will be much higher for a six year period. Higher Education institutions use the subsidy for payment of staff and maintaining facilities. Universities in South Africa are therefore competing to recruit students who will earn more comprehensive and faster turnovers for subsidy purposes.

Another reason for concern, relevant to this research, is the unacceptably high drop-out rate of students in the Higher Education sector. Widening participation mechanisms implemented by Higher Education institutions, without managing students to become successful graduates, will be irresponsible (cf. Figure 2.6). In a detailed study (Bunting 2004c:73-94), the dropout rate of 120 000 of the undergraduates who entered the South Africa Higher Education sector for the first time in the 2000 academic year, is illustrated (see Table 2.3 below):

**Table 2.3** ***The Dropout Rate of the 2000 Cohort of First Time Entering Undergraduate Students in South Africa***
(Adapted from Bunting 2004c:73-94)

| Detail | **Universities (%)** | **Technikons (%)** | **Total (%)** |
|---|---|---|---|
| Dropped out at the end of 2000 | 25 | 34 | 30 |
| Dropped out at the end of 2001 | 9 | 13 | 11 |
| Dropped out at the end of 2002 | 7 | 11 | 9 |
| Total drop-out 2000 – 2002 | 41 | 58 | 50 |
| Graduated in 2002 or 2003 | 26 | 19 | 22 |
| Studying in 2003, but not completing | 33 | 22 | 28 |
| **Total in cohort** | **59 000** | **61 000** | **120 000** |

The above table indicates that 30% of the total cohort (approximately 36 000) of the 120 000 first-time entering Higher Education undergraduates dropped out at the end of their first year of study. A further 20% (approximately 248 000) dropped out after either two or three years of study (generally known as the "revolving-door effect"). At least 50% (60 000 students) of this cohort had dropped out by the 2003 academic year, with only 26 500 (or 22%) graduating by the end of their third or fourth year of study.

The new Higher Education funding framework determines the funds allocated to every university by government per year (RSA DoE 2008a). According to the new formula, 65,7% of institutional subsidy will be allocated to teaching inputs (based on enrolments), 11,6% to teaching outputs (successful students who exit the Higher Education institutions), and 14,7% to research outputs (publications and conference proceedings). This is a radical change to the previous funding system (where the emphasis was on teaching output). The framework also introduces capping (limiting enrolments) of student numbers to ensure management of enrolment at a national level.

Major issues on student enrolment planning raised in this report (RSA DoE 2004a:4) were:

- The pattern of growth in Higher Education was neither affordable nor sustainable. The growth affected affordability and sustainability and was influenced primarily by inefficiencies in the system. "Dropout rates are high, and success and graduation rates are lower than they should be" (RSA DoE 2004a:5).

- Enrolment numbers must be controlled (at systemic and institutional levels) by utilising the mechanism of government funding and approval of three-year rolling plans per institution.
- In order to stabilise government funding to institutions capped totals per year will be used to regulate the teaching inputs.
- There will be no limitation on output (teaching and research).

The reasons for the student drop-out rate can be attributed to any of the following (and others): financial difficulties, inability to adjust to Higher Education, lack of counselling, under-preparedness, incorrect study habits, and immaturity (Bunting 2004c:73-94 and Scott in Bitzer 2009:21).

### 2.3.3 Synthesis of policy influences on Higher Education in South Africa

The post-1994 Higher Education "Renaissance" is evident in many areas applicable to students, staff, curriculum and governance. Figure 2.3 (below) indicates the alignment of influences of the abovementioned policies with the purpose of this study, namely to identify responses resulting from challenges with reference to the changing Higher Education landscape that influences student academic success.

The previously discussed policies converge into four key strategic issues of concern for this investigation, namely i) policy drivers, ii) differentiation, iii) reconfiguration, and iv) public perceptions.

i) The relevant policy drivers for ideological discontinuation in terms of institutional values and resource allocation are shown in Figure 2.3. The progression from equity to efficiency, massification to reponsivity, as well as access to throughput, increases the credibility of these policy influences in the Higher Education environment.

ii) The issue of differentiation is clearly encouraged by programme diversity and promoted by institutional diversity. It finally guides the top-down notion of differentiation by programme mix and institutional mission.

iii) A reconfiguration of the Higher Education landscape, with a reduction in the number of institutions via mergers and increased collaboration among institutions, changed values and impacted on resource allocation.

iv) There was a change in public perception of Higher Education, from inefficiency and lack of contribution to national and regional developmental needs.

This study will consolidate the policy drivers stemming from the policies discussed, partially encapsulating differentiation, reconfiguration and public perception. The aforementioned policies challenge Higher Education to respond, with the response presented as an optical lens system – "shedding more light" on the implications (the researcher's own presentation). The policy drivers and responses are presented in the metaphor of a lens system converging and diverging light, as shown in Figure 2.3.

In Figure 2.3, the Higher Education system sends light rays via the six selected policies represented by six light sources. Each of these policies has emergent issues (shining from the light source) entering a concave lens, from where light is refracted in a diverging direction. These proposals represent light rays entering a second lens, namely a convex lens, which converges light rays to six responses of higher education. The responses are policy drivers directing the following sections of this study, namely enrolment management, access, quality, learning programmes, institutional governance and scarce skills.

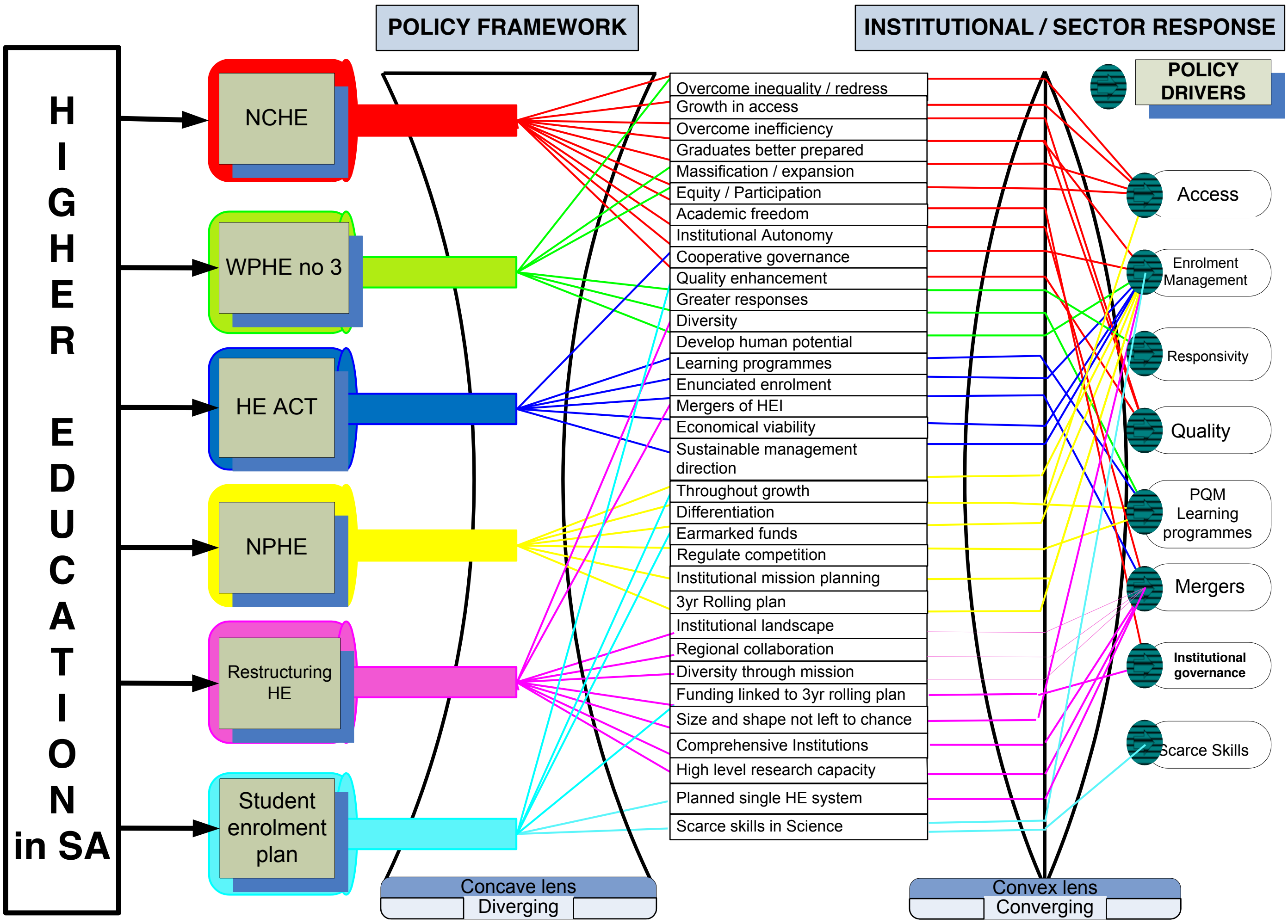


***Figure 2.3*** **Policy drivers stemming from major policies in HE**

The above issues resulted in adjusted strategies to strengthen the transformation of the Higher Education domain via efficiency, quality, reponsivity and differentiation. Domain expansion will be only brought about with planned and approved strategies in new legislation. The emphasis on broadening access, followed by increased throughput (clearly directing the quality of access), will also determine funding, which in turn will be linked to three-year rolling plans – a completely new paradigm in Higher Education. The reaction of the Higher Education sector would firstly be enrolment management, to be discussed in Section 2.3 of this chapter.

Secondly the study will focus on bridging mechanisms and strategies from the point of access to the point of successful delivery, which will then amplify Science programmes. This continuum (Figure 2.4) can be visualised as follows:

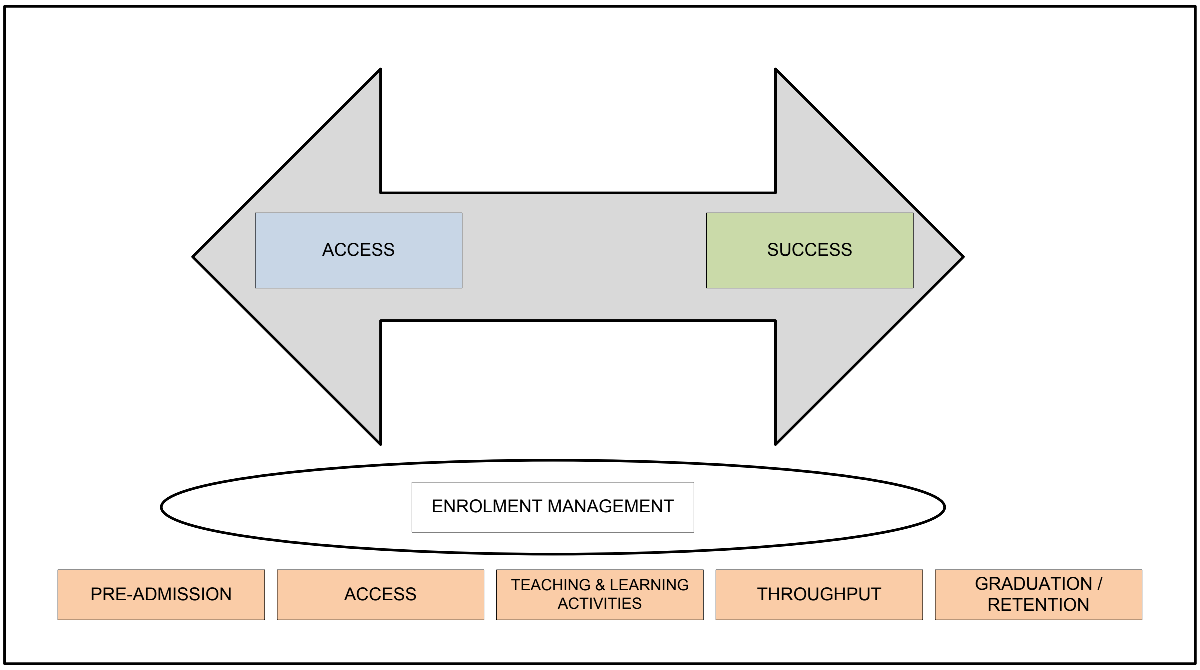


***Figure 2.4*** **Continuum from access to success**

Two of the most relevant policy drivers identified by the majority of the policies in Section 2.3.2 are enrolment management and access. Prospective students apply for enrolment in Higher Education and the process of enrolment management commences. Pre-admission processes (mostly correspondence) is followed by access and admission into a particular academic programme. In many institutions, these two phases are driven by administrative processes and academic policy. In the opinion of the researcher, the phases most neglected, are the linking of the teaching and learning activities and throughput with the essence of enrolment management. Lecturing academic staff may not have any knowledge of throughput, as they are mostly concerned with their own disciplines and modules (as part of the programme).

## 2.4 ENROLMENT MANAGEMENT AS A RESPONSE TO THE POLICY FRAMEWORK OF SOUTH AFRICAN HIGHER EDUCATION

In the section above (cf. Section 2.3), major policies that initiated change in the South African Higher Education sector were reviewed. The respective policies initially focused on broadening participation and (staff and student) equity, but the particular perspective gradually expanded to include the quality programmes offerings (qualifications) and the provision of quality "products" (i.e. graduating students). This brought about a 'new' approach to student enrolment in the Higher Education sector.

Access to South African universities has gradually been broadened across the board (RSA DoE 1997a:8-10). In addition, institutions are also required to implement management strategies to (a) ensure that an increased number of students graduate successfully, and (b) adopt sound enrolment planning principles and practices so that they can receive optimal subsidy. This implies that institutions will have to implement strategies and processes to optimally gain from the new efficiency policy trajectory. The former impacts quite significantly on the research problem(s) posted by this study, mainly because Science and fundamental Science programmes are typically regarded as scarce skills offerings and Science students often face daunting challenges to meet programme academic requirements.

In Figure 2.5, the outline for the following section regarding the origin and a conceptualisation of enrolment management is presented.

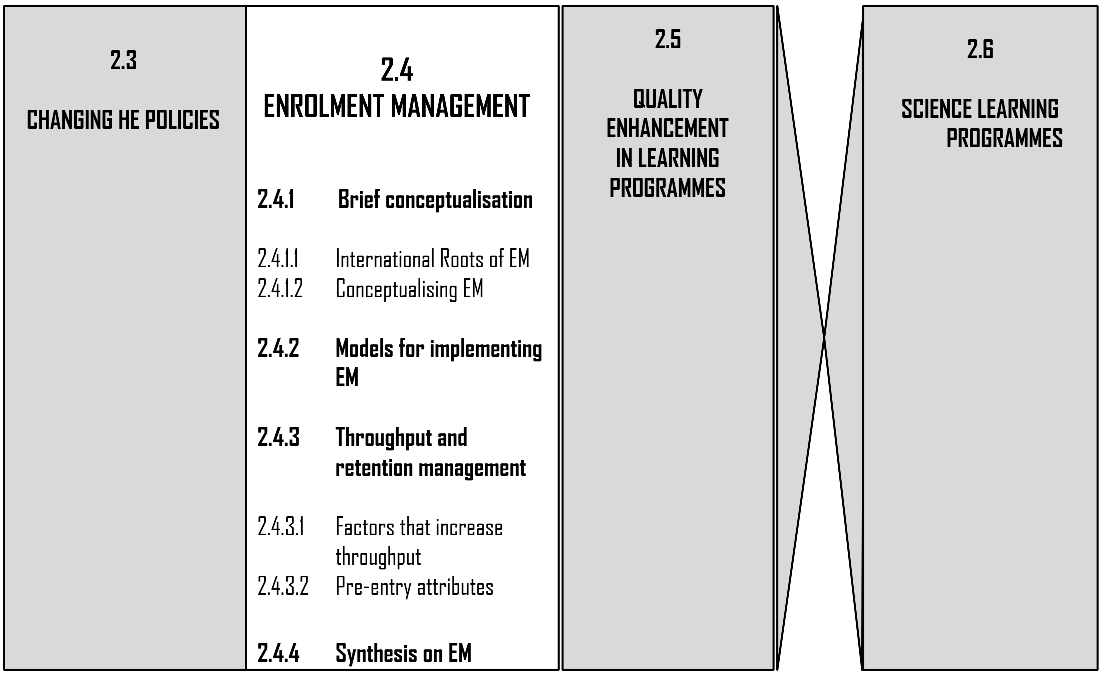


***Figure 2.5*** **Enrolment management as a response to the policy framework in South African HE**

### 2.4.1 A brief conceptualisation of enrolment management

The Higher Education sector is required to respond to the national development agenda of access, redress and human resource developmental needs. These thrusts emphasise the importance of instruments such as planning, funding and quality assurance operating in an aligned system. No longer can the size and shape of institutions be left uncoordinated, while student enrolment - as well as programme offerings - should be informed by the aforementioned practices. Available resources will determine the basis of institutional size and shape, with quality and sustainability recognised as pillars not to be compromised. The abovementioned needs and thrusts initiated the development of enrolment management in the Higher Education sector.

#### *2.4.1.1 The international roots of enrolment management*

As with many other Higher Education trends, enrolment management also began in the United States of America (USA) at the esteemed Harvard College (Coomes 2000:5-7). The records indicate admissions at Harvard documented from 1646, with a test in Latin and Greek allowing students access into the college. In 1770, Harvard enrolled 413 students (mostly sons of the wealthy), with Higher Education also becoming available to the sons of farmers from 1862 onwards. In 1890, the equity agenda in the United States of America expanded with the provision of educational opportunities to freed slaves (states would be penalised by loss of federal grant support if disobedient); although slaves were not allowed into existing grant colleges but rather 'their own' colleges for African Americans. The position of admissions officer can be traced back to medieval universities, and later to the office of registrar of colleges.

In the United States of America, the portfolio of Dean of Admissions was already functional in universities by the year 1920. This position included the responsibility of ensuring that 'prepared' applicants applied for college admission. From the early 1930s, there is evidence of funding and student aid being linked to the admission of students. After World War II (1946), President Harry Truman of the USA appointed a Commission on Higher Education to examine the functions of Higher Education and ascertain in what way this sector could function at its best. By 1970, college enrolment in the USA had increased (mostly due to an increase in female and coloured students) with an unbelievable 120%, and since then, research has been conducted on drop-out rates, attrition and student motivation for studies (Coomes 2000:5-7). More than three decades ago, Tinto (1975) and Astin (1993) were researching the student attributes that relate to academic success.

According to Coomes (2000:8), another perspective on enrolment management categorises the government involvement. A distinction can be made between "interventionary" and "supervisory" states. In the interventionary state, the government involves itself in the enrolment system by attempting to 'control' the nature of student input. Such enrolment systems are funded mainly by the government, e.g. in Egypt, China, the Czech Republic, Ghana and Tanzania. In the case of the supervisory state, the government underwrites the Higher Education system, without actually directing it. The supervisory state allows institutions to take responsibility for admission, as is the case in New Zealand, Canada and Texas (in the United States of America).

According to Dennis (1998:1), changes in the economy and society, demographics, technology usage, and financial aids in the United States of America, still influence the involvement of government to a large extent. During the 1970s to 1980s, the initiation and development of enrolment management in the Higher Education sector in the United States of America were basically directed by the following factors:

- A decline in the number of high school learners who could successfully make the transition to Higher Education.
- The perceptions of increased competition among universities for potentially successful students.
- The published research findings on determinants of student persistence and choice of institution (especially among non-traditional learners).

The above factors seem rather similar to the current situation in South Africa, where broadened participation policy initiatives admitted a large number of first-generation students into the Higher Education system.

#### *2.4.1.2 Conceptualising enrolment management*

Enrolment management has long been accepted as a concept typically associated with financial management divisions of Higher Education institutions, with academic staff members not being involved, other than in determining admission requirements for programmes (cf. Figure 2.6). The following attempts to define the concept indicate that enrolment management should in fact be the joint responsibility of all stakeholders within Higher Education institutions:

- "A comprehensive process designed to help an institution achieve and maintain the optimum recruitment, retention and graduation rates of students … [a]n institution-wide process that embraces virtually every aspect of an institution's function and culture" (Coomes 2000:69).
- "…forecasting trends that will likely affect Higher Education and using effective research to effectively plan for the future…" (Dennis 1998:4).

- "A systematic, holistic, and integrated approach to achieving enrolment goals by exerting control over those institutional factors shaping the size and characteristics of the student body. It encompasses all activities associated with attracting and retaining students, including marketing, recruitment, financial aid, retention services (including orientation and advising), and instruction. It also involves examining institutional mission, programs and service offerings, organisational structure, and resource allocation. The enrolment management process relies heavily on the use of pertinent data and information for informed decision-making" (Canadian National Enrolment Management Survey 2002:1).

In reviewing the three definitions above, the researcher views enrolment management as a continuous strategy (cf. Figure 2.4) or process and not a once-off event. The need for scientific planning and knowledgeable inputs from Higher Education practitioners from all institutional spheres emphasises the importance of this integrated approach. Dennis (1998:8) expresses the meaning of enrolment management in practical terms:

- Knowing what makes a student enrol at an institution.
- Understanding the link between students who enrol, withdraw and persist.
- Knowing how students pay for their education.
- Preparing strategically to meet future enrolment and financial needs of an institution.
- Linking enrolment management to retention management.

For the purpose of this study, the following working definition of enrolment management will apply:

Enrolment Management is an *integrated approach* to achieving enrolment goals by *recruiting students* with the *potential for success*, *ensuring that meritorious students graduate*, and *retaining meritorious students* in postgraduate programmes (cf. Figure 2.6). Enrolment management involves service and support strategies from an involved management with sound and transparent resource allocation. The enrolment management strategy or culture of an institution relies on a team approach where academic, administrative and institutional management jointly strive to enhance the student experience and optimally manage funding by means of collaborative planning and execution.

Enrolment management thus focuses on longitudinal care and comprehensive student education (Huddleston 2000:71) and typically includes an integrated approach to the following functions and/or structures: student marketing and recruitment; admissions and registration; student support services; costing and financial aid; academic and career counselling; and academic development and assistance programmes (Coomes 2000:13; Huddleston 2000:71). Institutional research and planning, as well as student orientation and retention programmes, also form part of this multi-disciplinary approach to enrolment management. All these aspects will be relevant to this South African-based study, as the successful graduation of students from Science programmes initially depends on well planned targeted marketing efforts to recruit (mostly under-prepared) students with sufficient potential from schools that mostly lack qualified Science and Mathematics teachers (Pandor 2008). Student admission solely based on Grade 12-results will be insufficient if integrated and adequate orientation, support (counselling and assistance) programmes and retention strategies are not in place.

### 2.4.2 Models for implementing enrolment management in institutions

Universities in South Africa are obliged to establish enrolment management systems for national policy (especially the NPHE) to be successful and considered seriously. The implementation of an enrolment management strategy in an institution can be managed by a committee, a person in an appointed position, or even a dedicated enrolment management unit. Kroc and Hanson in Howard (2001:26) and Black (n.d.:3-4) describe the typical stages in the evolution of enrolment management structures in an institution:

- Firstly, enrolment management structures typically begin with committees. Committees are useful for educating the institutional community and addressing enrolment management issues if there are no difficulties in need of immediate action (Howard 2001:27). Such a committee is usually advisory in nature, lacking sufficient ownership and authority to implement an enrolment management plan, or to obtain the necessary resources (Black n.d.:3).
- Secondly, institutions can choose to appoint a staff coordinator. This employee will typically be a member of middle management, such as a dean or director, responsible for coordinating marketing or enrolment management activities (Black n.d.:3 and Howard 2001:30).
- Thirdly, a system - commonly known as a matrix system - exists where a senior administrator will attempt to align academic and administrative processes in support of enrolment management. Formal reporting lines remain in place, but relevant units or divisions also report to the enrolment management administrator (Howard 2001:31).

The more pertinent and perhaps sophisticated enrolment management-division model requires major reorganisation by the institution to establish a formal enrolment management office. This division can report to any one of several members of top management, but typically to the deputy vice-chancellor concerned with academic matters. Such a division can focus on admissions, financial aid, central administration, academic advisory services, residence life, student activities, career services, academic support services, institutional research and professional development functions (Howard 2001:31).

Enrolment management models differ across institutions, depending on institutional goals, financial circumstances, internal culture, and the competitive environment (Huddleston 2000:68). Ideally, enrolment management should be viewed as a strategy rather than a collection of activities, and may therefore cut across institutional structures (Dennis 1998:9). Enrolment management is not the responsibility of one person, but should be based on mutual ownership of all staff members. Typical ways of implementing such a system include coordinating it via a formal committee, implementing it via a matrix system, or managing it as a comprehensive enrolment division (Huddleston 2000:68). Enrolment management demands that the student needs be placed above intra-institutional politics that determine the implementation of optimal enrolment management in an institution.

The models described above indicate the importance and range of responsibilities of enrolment management. The focus of enrolment management remains the student – recruitment and retention of successful students. Many administrators will claim that enrolment management remains the business of the planners and accountants within an institution. It can however be argued that efficient student throughput is best managed by academics interacting with students on a daily basis. Management of the academic journey for students, from orientation through first to final year, is the concern of every academic staff member. Academics should be developed in respect of professional skills and competencies to become better lecturers who regularly share subject and enrolment management-related knowledge and research with their students.

The preferred enrolment management strategy (for the researcher) is the appointment of a senior academic (preferably the Vice-Dean) by a Dean of Faculty to manage the faculty-specific enrolment management processes and culture in collaboration with academic and administrative staff members.

#### *2.4.2.1 The student-flow funnel model for enrolment management*

From studies conducted by Cronjé (2006:9) at the University of Johannesburg (UJ), the need for a new approach to student admission and success become clear. Cronjé proposes that enrolment management be adopted "…as the framework according to which student admission and success is structured in a holistic manner", captured by the so-called student-flow model (compare Figure 2.6).

In an ideal situation, the solid vertical lines (on the sides) of the funnel shape would be parallel, indicating that the majority of students who are targeted in the institutional mission to become successful students. A broad student population is recruited and enrolled and should then be supported to achieve success. The funnel narrows down as the number of students also decreases through all the various phases. The Higher Education sector should strive preferably to retain an increased number of students in the system and attempt to maintain a square shape (indicated by the solid 'square'). According to this student-flow model, the purpose of enrolment management should be is to ensure that the institution enrols the correct mix and number of students to fulfil its mission and to ensure that the maximum number of enrolled students achieve their academic goals (Cronjé 2006:10). This model thus promotes the alignment of the institutional mission with student success, and the idea of an enrolment funnel (symbolising the 'journey' that potentially successful students should typically follow) captures the student-flow model rather appropriately.

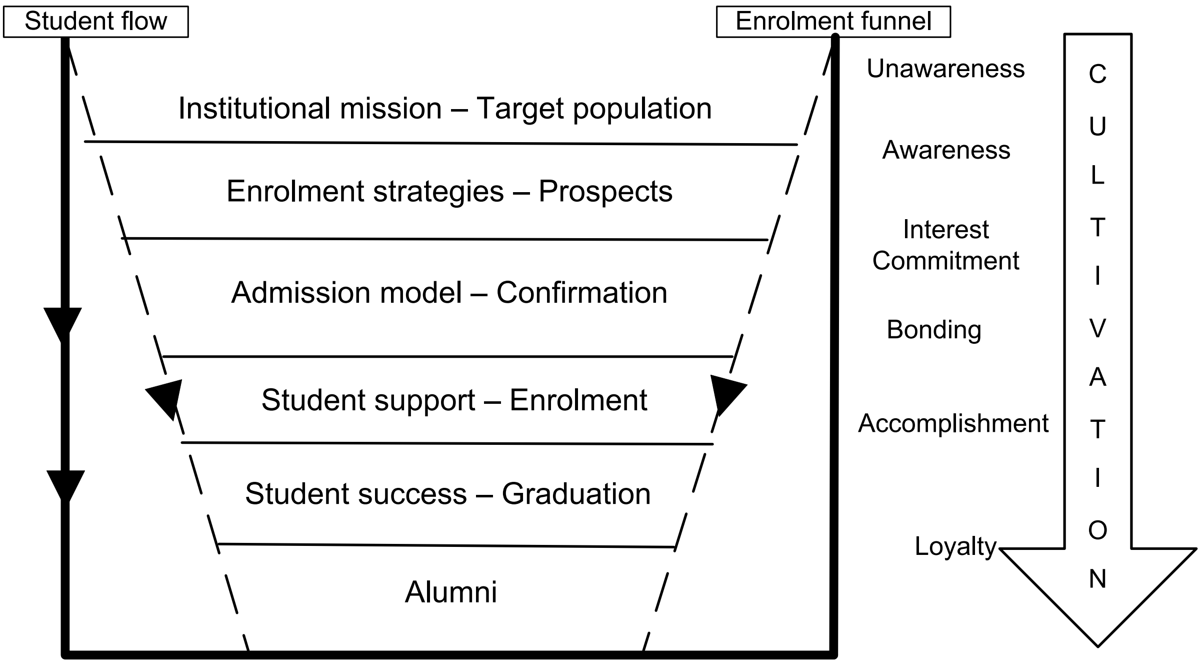


***Figure 2.6*** **Student-flow model**
(Adapted from Cronjé 2006:10)

In Figure 2.6, the right-hand side of the funnel represents the seven phases from recruitment to alumni-status, with the values and attitudes associated with every phase highlighted appropriately (Fleming College n.d.). This model stipulates the development of alumni through six phases: from pre-access to post-success or from 'unaware' to 'loyal', as depicted in Figure 2.6.

The development of the aforementioned attitudes will depend largely on the culture and academic environment of the institution, as manifested in every lecture hall and by all staff members - an 'inviting' student experience established by the underlying ethos of the Higher Education institution and maintained in every lecture hall, laboratory and activity. In Figure 2.6, a large group is recruited with only a few becoming successful and eventually alumni. This study envisages increased numbers of successful students, which, in turn, will rely on who is granted admission and what support is provided.

The implementation of the funnel demands that management from various specialised units contributes to the provision of successful graduates. This integration requires planning, structures and commitment from all. Enrolment management entails much more than analysing the new students' applications, administrating admission requirements and student registrations. The strategy to manage enrolment depends on the size and the shape of the institution, its culture or 'ethos' and the level of management support (preferably from the highest level). Enrolment management is a Science and an art, strategically and scientifically planned and creatively harmonising the real student experience with the institutional culture.

A successful enrolment management system is entirely dependent on integrated ownership and leadership, proactive and cooperative staff teams, a willingness to take risks when required and finally, on sometimes prioritising student needs above individual staff or institutional needs.

In this section, the student-flow funnel - from recruitment (where engagement with the student commences) to graduation (where successful "products" are delivered) and beyond (because the engagement does not end here) - was deliberated. In order to optimally deliver their graduates, universities will be obliged to manage student throughput and retention – two crucial student-flow and enrolment management catalysts.

### 2.4.3 Throughput and retention management

All South African universities have emphasised and spent many hours and substantial resources on the construction and implementation of strategies to comply with new legislation and policies. The concern about inappropriate graduate output from the Higher Education sector echoes statements in the National Plan (RSA DoE 2001:19) and will be repeated often in future: "These poor graduation and retention rates and high dropout rates are unacceptable and represent a huge waste of resources, both financial and human. For example, a student dropout rate of 20% implies that about R1,3 billion in government subsidies is spent each year on students who do not complete their study programmes. These funds would go a long way, not only in financing the expansion of the Higher Education system, but also in providing the much needed funds for redressing the inequities of the past. Moreover, the cost to those who drop out, in terms of the moral and psychological damage associated with 'failure', is incalculable."

Table 2.3 indicated the drop-out rate of first-year students during their Higher Education studies and is reported to be unacceptable 30% (i.e. an estimated wastage of R1.95 billion). In South Africa, the fragmented school system should be blamed for many difficulties currently encountered in Higher Education, but according to Davig and Spain (2004:1), the attrition rate in the public Higher Education sector in the USA is also less than exemplary at 25%, despite their schooling system that has been relatively stable for more than five decades. Clift (2003:6) reviewed the retention patterns in the United Kingdom (UK) and also reported a drop-out rate of 25%.

The final graduation rate of only 22% of enrolled South African students (derived from Table 2.3) once again emphasises the importance of enrolment management. The admission of students according to their potential is a critical challenge. Another challenge is to provide prolonged support and management to all students, in order to have them progress through the funnel (cf. Figure 2.6). Institutional management (with policies and processes) is required to ensure optimal student throughput and success (the findings captured in Table 2.4 below are indicative of this statement).

The table shows that only 25% students in South Africa graduated in three years, and 20% in four years (it should be noted that these are the official minimum study years). Students entering Higher Education, but failing to make sufficient progress through the "funnel" (cf. Figure 2.6), are wasting valuable space and resources.

**Table 2.4** ***Drop-out and Graduation Rates***
(Adapted from Bunting 2008:5)

| **Drop-out rate (in three-year degree programmes)** | | **Graduation rate (in three-year degree programmes)** | |
|---|---|---|---|
| Drop out after 1 year | 20% | Graduation in 3 years | 25% |
| Drop out after 2 years | 10% | Graduation in 4 years | 20% |
| Drop out after 3 years | 3% | Graduation in 5 years | 15% |
| Drop out after 4 years | 2% | Graduation in 6 years | 5% |

The above problem can possibly be due to the quality or attitudes of students entering the system, or within the Higher Education system, or many other factors (that might emerge from this investigation). Scott (2007) claims that the South African schooling system will not improve significantly over the next number of years. This places a burden on Higher Education to "do things differently".

### *2.4.3.1 Factors to consider for increased throughput*

The Higher Education sector must find solutions from within the sector to enhance student throughput without compromising quality. Factors that might make a major difference to throughput rates are the following (Tinto 1993:45):

- Appropriate curriculum design (including foundational provision that students need to succeed).
- Increased classroom interactions (including an investigation into contact time and class sizes).
- Accommodating diversity and changing the status of academic achievement. Tinto (1993:45) highlights aspects such as personal problems, career demands, dissatisfaction with the academic environment and incongruence with institutional values as main contributors to student drop-out in Higher Education. Students withdraw (Tinto stated then) when they do not integrate into the social and academic spheres of university life "…from where they derive their values, academic intentions and commitment to the educational process." Tinto's statement can be applicable to the current South African Higher Education sector, because it is, perhaps more than ever, relevant.
- Financial reasons (being the key issue responsible for drop-out as mentioned by Dennis 1998:79). It is however, debatable whether increased financial aid will guarantee higher retention rates.
- The actual reason for dropping out is more often than not the students' feelings that they do not belong.
- Courses that are too challenging or students who were under-prepared for the particular programme or institution (placement).
- Academic under-preparedness is perhaps the largest contributing factor to increased attrition, according to Dennis (1998:80).

*2.4.3.2 Pre-entry attributes to consider for increasing throughput*

Clift (2003:5) lists a few pre-entry attributes that mould the values, intentions and commitment of students as the following:

- The level and type of pre-university education assist students in making informed and reasoned decisions.
- The family experience of education, as well as their own abilities, strengthens the choices and wellbeing of students. Students from a family background with Higher Education experience usually have a "ready-made support structure" (Clift 2003:6) as they are knowledgeable and have experience of the transition.
- University expectations create a new and challenging experience, with inexperienced family support placing pressure on an already major adjustment.

Tinto (1993:6) proposes that institutions take action at two specific points, namely: "…at the point of developing goal and institutional commitment", and where "… commitment is being strengthened by integration into the social and academic spheres of university life." Although nearly four decades in the making, Tinto's model in Figure 2.7 (1993:5), presents a conceptual scheme for student drop-out. These factors and attributes are currently just as relevant.

In the diagram below (cf. Figure 2.7), pre-entry attributes are indicated as family background, individual attributes and schooling, all these fitting into each other like puzzle pieces. The attributes influence the development of a personal goal for students, as well as commitment from the institution. Institutional commitment is strengthened by academic integration (performance and intellectual development), as well as social integration (peer group and lecturing interventions), once again fitting as puzzle pieces. Both student and institutional commitment guide the final decision about remaining in the system (completed puzzle) or dropping out (loose pieces).

Development and strengthening of this commitment remains a challenging task, relying on family, personal and school culture, and other attributes. Maintaining personal and institutional commitment involves a great effort from faculty managerial and support staff and, specifically, course lecturers (Clift 2003:6). Pre-admission characteristics and background variables influence the student integration into social and academic spheres, which in turn influence student performance and persistence.

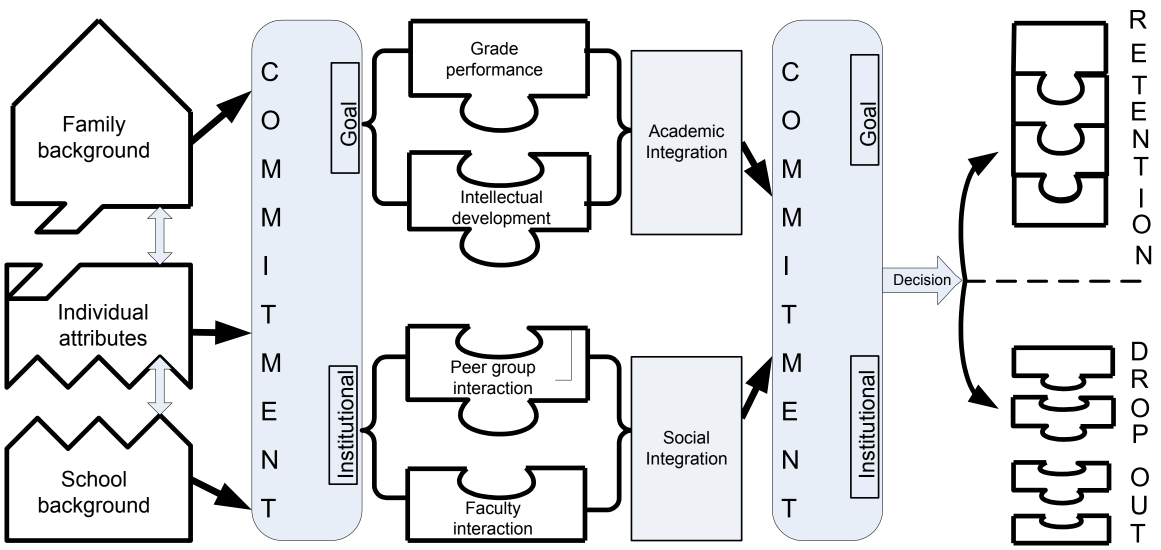


***Figure 2.7*** **A conceptual scheme for drop-out from college**
(Adapted from Tinto: 1975:95)

Mackie (in Clift 2003:9) takes a psychosocial view of drop-out or withdrawal and elaborates on the importance of role identity and peer intervention. Her research (performed in Bristol, UK) indicated that students who leave the institution after a short while usually suffer from homesickness and have an inability to separate from their families. They leave university not because of the difficulty to adjust but because of an inability to deal with separation problems.

Smith and Beggs (2002:2) propose an alternative support system for the first-year experience, namely the Triple C: **c**are, **c**ontrol and **c**onsistency. First-year tutors should be caring, assist with controlling the new environment and be consistent in their approach. At the Glasgow Caledonian University (in Smith and Beggs 2002:4), this system was so successful that in two years' time, the student retention increased by 18% for Natural Science and 17% for Engineering students.

Student throughput in SET programmes in Higher Education is of particular concern for this study. The graduation rate of Science students in South Africa is alarmingly low, with fewer than one in five (in fact only 18%) completing their three-year studies in that time. Fewer than four in ten (38%) complete the four-year professional degree in that time. Participation of Black students in SET programmes (at 12%) increased slightly over the past few years, but still only one out of every three Black students graduate within five years (Scott 2007).

The South African government has indicated the urgency of students completing their studies, as stipulated in the WPHE (1997a:53). Dedicated additional earmarked funding is provided as an incentive to encourage improved completion of studies. Several key performance indicators of student success emerged in international Higher Education in the 1990s, of which student persistence (also serving as an indicator of student satisfaction) and retention are most prominent (Levitz, Noel & Richter 1999:31). In the USA, Australia, Canada and UK, retention management has developed to a well researched and scientific specialisation area, with the credo: "(T)he success of an institution and the success of its students are inseparable" (Levitz *et al*. 1999:40).

Higher Education in South Africa must consider the management of retention, as proposed by Levitz *et al*. (1999:41). A long-term strategy develops a campus culture with the following characteristics:

- Creating a student success structure.
- Intensive contact with at-risk students.
- Academic advisors understanding the needs and motivational levels of students.
- Lecturers actively engaging with students and taking initiative for the relationship.
- Attention being paid to the adjustment and individual needs of students.
- Celebration and recognition of successes by members of staff who are dedicated in their quest to motivate students to move to the next level.

A tailor-made application of the abovementioned characteristics by South Africa universities (each according to its own institutional culture) will change Higher Education radically. The current perceived culture (and expectation) is still that students are relatively well prepared (based on school grades and experience) and mature when arriving on campus. Another perception still held by many lecturers is that students who fail their university studies should not have been admitted in the first place. It is only over the past two to five years that South African institutions have become aware of intervention needs and have actively explored First-Year Experience (FYE) and academic orientation. Student enrolment management and retention-enhancing initiatives are well known concepts in many foreign institutions, but have yet to be formalised in South Africa Higher Education. During scientific planning and structuring of programmes, most of the required relationships between students and the institution are established – relationships that could mean the difference between eventual Higher Education study success and student experiences of failure.

### 2.4.4 Synthesis on enrolment management

In Section 2.3, the response of the South African Higher Education sector to major policies on broadening participation and equity is viewed from a particular stance. The role of enrolment management in contributing towards student success is the underpinning theme. It was concluded that optimal enrolment management requires a long-term, continuous and integrated approach from all universities. It commences with the recruitment of potentially successful students and "ends off" in the years beyond graduation, when students enter society and the work place market, and yearn to initiate follow-up studies at the same institution. Implementation of such an enrolment management system requires active and structured involvement and commitment from all institutional stakeholders, especially academic lecturing staff who are frequently at the interface of the institution and its students.

The enhancement of the quality of learning programmes will subsequently be discussed, as quality assurance and promotion have been identified as crucial and influential policy drivers (see Section 2.2).

## 2.5 QUALITY ENHANCEMENT IN LEARNING PROGRAMMES IN RESPONSE TO CHANGES IN HIGHER EDUCATION IN SOUTH AFRICA

The following section emphasises the changing notion of quality, specifically, in learning programmes. The policies reviewed in Section 2.3 clearly focus on quality in Higher Education. The researcher believes that the changes required from institutions in response to the new Higher Education policy framework highlight an enhancement of institutional quality and a need for meticulous quality management at all institutional levels. Institutional quality, based on quality learning programmes should enhance student success.

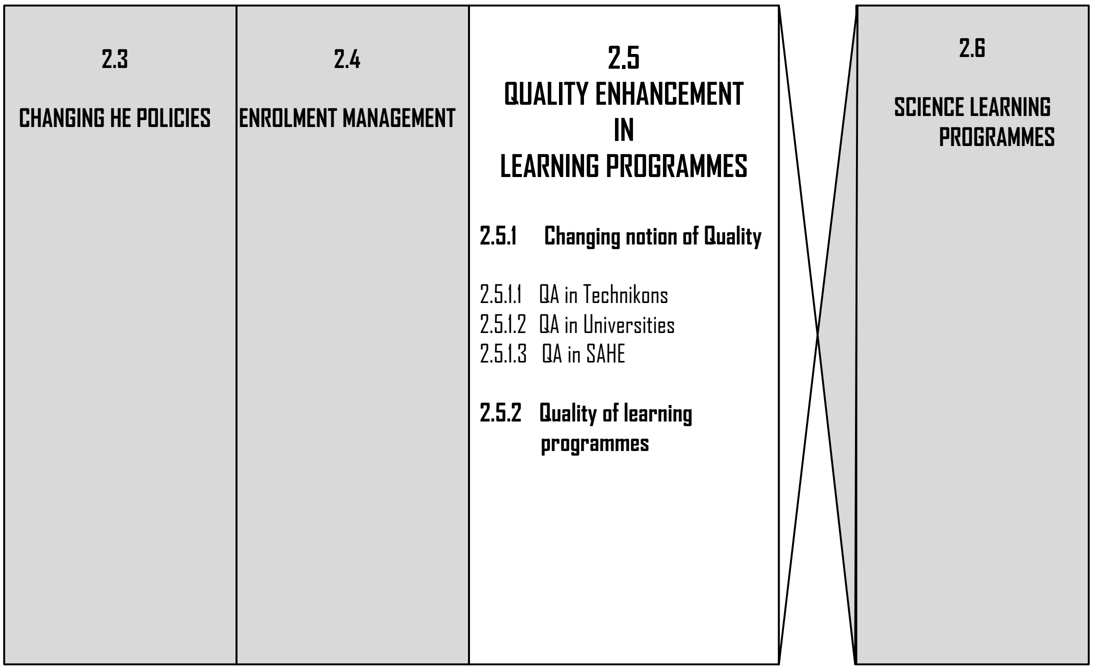


***Figure 2.8*** **Quality enhancement in learning programmes in response to changes in HE in South Africa**

### 2.5.1 The changing notion of quality in the South African Higher Education sector

Against the background of its fragmented past, the new South African Higher Education sector was obliged to establish a single national quality assurance system (Hay & Fourie 2002:115–131). Previously, the Higher Education sector was divided into technikons (now universities of technology) and universities. This section will outline assurance and specifically, quality care in technikons and traditional universities and will refer to government quality structures (such as the Council on Higher Education and Higher Education Quality Committee (HEQC) (CHE 2000b).

#### *2.5.1.1 Quality assurance in traditional Technikons in South Africa*

The Technikon Education Act (Act 88 of 1986) established the Certification Council for Technikon Education (SERTEC) as an autonomous statutory body that promoted quality assurance in traditional technikons. The purpose of the Council was to ensure that corresponding technikon certificates issued by the Council would represent an equal education and assessment standard. The first Council of SERTEC decided (in July 1988) that the monitoring of quality education in technikons would be its main focus. It would do so by means of peer evaluation committees, in line with common practice across the world (CTP 2004:18). While the legislation granted SERTEC significant power to hold technikons accountable for quality in their institutions, its approach was soft and reflected due sensitivity to the emerging autonomy of technikons, as well as to the need to secure cooperation of the technikon movement, rather than to provoke its resistance. As a result, all the requirements for monitoring quality at technikons were drafted in cooperation and consultation with the Committee for Technikon Principals (CTP) (CTP 2004:15).

The picture that emerges is one of continuous re-defining of the specific nature of SERTEC evaluation, with a strong focus on compliance.

#### *2.5.1.2 Quality assurance in traditional Universities in South Africa*

The first move by the traditional university sector to formalise quality assurance was the establishment of the Quality Promotion Unit (QPU) by the South African Universities' Vice-Chancellors' Association (SAUVCA) in 1995 (Jacobs & Du Toit 2006:304). The QPU commenced operations in a time of relatively minimal accountability (according to Brink in Strydom, Lategan & Muller 1997:129), with an emphasis on quality promotion (more on improvement than on assurance). South African universities probably had mechanisms for ensuring quality input (staff and students) and output (graduates or postgraduates) in place, but paid little attention to promoting the quality of processes, especially the core functions of teaching and learning, research and community engagement.

In the years preceding the establishment of the Quality Promotion Unit, quality at most universities had been associated with excellence and high, often internationally acclaimed standards. Jacobs and Du Toit (2006:304) mention the elitist view that South African universities had of quality, as if it were something very distinctive, only attainable by a few reputable institutions. However, since the views brought about by numerous pieces of legislation and various national policies (cf. Section 2.3), institutions have established that most of them were actually lacking formal quality promotion policies, processes and structures to meet the Quality Promotion Unit's audit requirements. Many institutions consequently resorted to some form of self-evaluation of academic departments and learning programmes. Wilkinson (2003:165) states that self-evaluation is at the "heart" of quality improvement.

#### *2.5.1.3 Quality structures in South African Higher Education*

As both the QPU and SERTEC were dissolved after the turn of the century, the CHE was assigned the responsibility of the national Higher Education sector for quality assurance and promotion. For this purpose, it established a permanent sub-committee, namely the Higher Education Quality Committee (HEQC) in 2001 (Smout 2002:6). The HEQC has the mandate to conduct quality assurance in the Higher Education sector in general, to promote institutional quality assurance (via audits), to accredit learning programmes, conduct national programme reviews, and develop quality assurance, promotion and management capacity across the sector.

The CHE (2004a:5) clearly signals its understanding of quality pertaining to a university's core business, as follows:

- Universities (as well as their faculties and programmes) must be fit for purpose in advancing the institutional mission and goals (institutional missions and goals also relating to national policy ideals, implying a built-in fitness of purpose perspective in the abovementioned fitness for purpose notion) (cf. Section 2.3.2.1).
- It must be transformative — the empowerment of learners as lifelong learners and striving to provide graduates who meet the demands of social and economic development in South Africa as another major quality challenge.
- Value for money—Higher Education must be cost-effective, with students (and their "sponsors") receiving a satisfactory return on investment (cf. Section 2.3.3 & Table 2.2).

In addition, when the CHE published its institutional audit framework and criteria (2004a and 2004b), another view of quality complemented the embedded frame of thinking pertaining to university education must also have a multi-client focus, implying that university education be tailored to meet the needs of all its clients (Srikanthan & Dalrymple 2003:126). In less than a decade, the traditional view that South African universities were excellent and could be satisfied that they were producing graduates par excellence was revised. According to Smout (2002:11) "…quality must be shown to exist, and the processes of monitoring quality for continuous improvement are what quality assurance is all about…" In a longitudinal study, involving several quality practitioners from international institutions in the USA, UK and SA, the following definitions of quality in Higher Education were expressed by the participants during three different workshops (Jacobs, Jacobs & De Bruin 2009). Quality in Higher Education to them is:

- *excellence*: maintaining and improving high standards;
- "*client" satisfaction* for multiple stakeholders;
- *consistency and coherence* in practice;
- a *contractual partnership* between the university and the student;
- *fitness for purpose:* advancing the mission and goals of the institution;
- a *transformative contribution* to the personal empowerment, societal and economic development of the institution as a whole;
- *value for money,* with the range of Higher Education programmes on offer; and
- *fitness of purpose* to meet national goals and priorities.

Quality in Higher Education then seems to involve students, teaching and learning, as well as responsiveness. It is not a checklist, a process (on paper) or an institutional administrative initiative, but indeed a relative, context-specific, dynamic and multi-dimensional concept.

### 2.5.2 Quality of learning programmes in South African Higher Education

More than a decade ago, the WPHE (1997a:17) recommended that the quality of learning programmes should be enhanced by integrating academic development approaches into main stream undergraduate curricula. Typical practices in this regard (CHE 2004b:8; CTP 2004:24; Jacobs & Gravett 1998:5 and Smout 2002:38;) include: faculty-specific foundation programmes; language skills development; numeracy, and cognitive skills development. Getting students involved in learning communities in their academic disciplines and even in residences can enhance their learning experience. Utilisation of student tutors and mentors is imperative for student success. Furthermore, investment in formal enrolment management and student retention programmes, inclusive of placement tests and student tracking, will ensure appropriate support.

Professional development of university lecturers to optimally fulfil their expected roles as facilitators of student learning will assist in creating a learning environment conducive to learning. The establishment of formal institutional teaching and learning committees that regularly monitor student development, support and throughput will direct quality assurance of learning programmes. Since 1999, a greater awareness pertaining to the kind of practices regarded as student-centered and learning-supportive have been detected in universities (Jacobs & Du Toit 2006:308).

There has been a significant increase in the number of student development and support strategies, with various desirable practices being implemented. The notion of a First-Year experience (FYE) is currently being piloted, academic orientation is being implemented, and the introduction of extended programmes for under-prepared first-year students is being advocated by government. There has been additional financial support for (especially) disadvantaged students, and support strategies (e.g. tutors, mentors and learning centres) have been funded and supported by institutional management. Coherent arrangements for the integration of the planning for design and management of academic programmes are visible and represent important indicators of the increasing effectiveness of Higher Education provision (RSA DoE 2006a).

The HEQC audit criteria (CHE 2004a) focus on the broad spectrum of core function-related institutional activities. The following HEQC criteria have relevancy for this research:

- The arrangements for the quality assurance of and support for teaching and learning enhance quality and allow for its continuous monitoring.

- The administration of academic programmes is conducted within the framework of an effective programme management system. Responsibility and lines of accountability are clearly allocated.
- Clear and effective systems are in place (including internal and external peer review) to evaluate programmes on a regular basis.
- The institution has effective procedures in place to facilitate the quality of the internal and external moderation of its assessment procedures and results, in order to ensure reliability and integrity of the qualifications it awards.

The relevance of the abovementioned quality criteria is portrayed against ‘effectiveness’ and ‘efficiency’, as stated in the discussion on national policies (cf. Section 2.3). The implications of the research performed by Angelo (1999) and Jacobs and Du Toit (2006:308) are that faculty quality ownership can be enhanced significantly by embedding it in the hearts of faculties by members of the academia themselves. It should be noted that enrolment management will be enhanced when faculty members engage with students. The aforementioned therefore claims that quality assurance lies within the immediate environment where the lecturer functions.

The challenge for fundamental Sciences lecturers is unique: Enrolment management (mostly throughput) of Science students and bridging the ‘gap’ from the school curriculum in these perceived ‘difficult’ disciplines need planning, perseverance and resources.

## 2.6 SCIENCE LEARNING PROGRAMMES IN RESPONSE TO NATIONAL NEEDS AND SCARCE SKILLS

Finally, this section will probe the response to policies, enrolment management and quality enhancement strategies specifically in Science education. It should be noted that in this investigation the term ‘student’ will be used in the university context. The term ‘learner’ will refer to individuals at school level. In the diagram below (Figure 2.9) the flow of this section is provided.

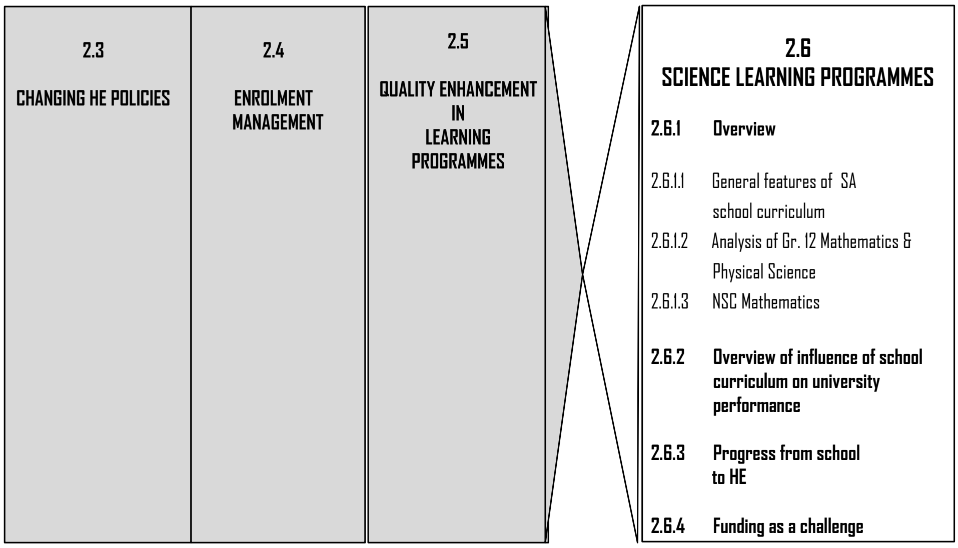


***Figure 2.9*** **Science learning programmes in relation to national needs and scarce skills**

In this section, the metaphor of a lens system (as presented by a bifocal lens) will be utilised to illustrate one of the policy drivers identified in Figure 2.3, namely scarce skills in Science.

The bifocal lens system depicted in Figure 2.10 consists of two different lenses moulded into a single system where the bottom portion magnifies the nearby object (e.g. reading material), and the top portion focuses on distant objects. Both objects can be perceived with the blink of an eye – seeing the closer detail (such as Mathematics and Physical Science as a gateway to general Science), as well as focus on the bigger picture - the scarcity of SET students and teaching/lecturing staff (at school and Higher Education level).

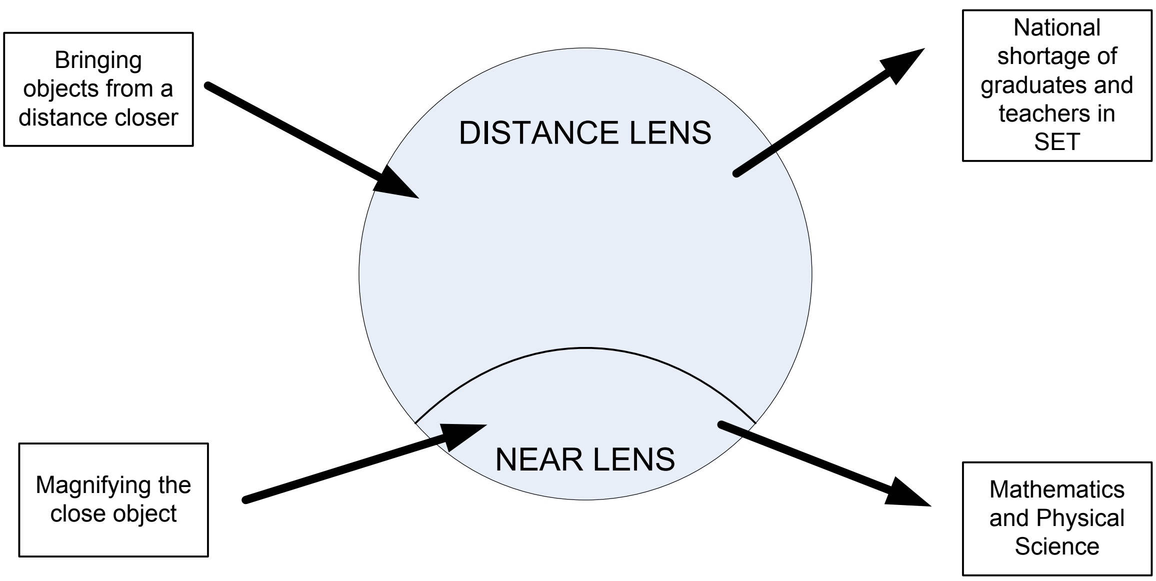


***Figure 2.10*** **Science as a scarce skill perceived through a bifocal lens**

The pool of potential students in **S**cience, **E**ngineering and **T**echnology (SET) is limited (cf. Section 2.6.1). This was identified as a national problem area (cf. Section 2.3). The throughput and success of these students rely on foundational knowledge and skills developed at school. According to the definition by CHET (2004:314), SET includes "…all majors in Science, Engineering and Technology (including Health Sciences)." This section elevates the importance of Science for two reasons: The scarcity of Science students in Higher Education and the monetary incentive for universities to build capacity in Science fields. The national shortage of SET graduates provided to industry will be discussed by reviewing the school curriculum, performance in Mathematics and Physical Science, the perceived gap from school to Higher Education and the funding structure in Higher Education in South Africa.

### 2.6.1 An overview of the current South African secondary school curriculum and performance

The South African secondary school curriculum has changed fundamentally since 1994. Jansen (in Beeld 31 December 2003:8) claims that curricula, like national flags and anthems, are some of the "… most contested symbols of any social transition. This change symbolises the shift in dominant values in transition societies." According to the DoE (2008a:3), the year 2008 was a year of "…enormous significance for education …" in South Africa. In 2007, the last Senior Certificate (SC) examinations were written by Grade 12-learners at the end of their secondary schooling. The new National Curriculum Statement (NCS) leads to the National Senior Certificate (NSC) and was introduced in Grade 10, from 2006 with 588 643 learners eventually registering for the Grade 12-examination in November 2008 (RSA DoE 2008b:3).

#### *2.6.1.1 General features of the South African secondary school curriculum*

The National Curriculum Statement does not differentiate between Higher and Standard grades (which the former curriculum did), and all candidates write examinations set at national level (no more provincial examinations). The outcomes of the above curriculum have constitutional and human rights principles ingrained in the development of the future citizens of the country. The NCS has three compulsory fundamental subjects: i) Languages, ii) Mathematics or Mathematical Literacy, and iii) Life Orientation. These three components provide the "…core skills for the intellectual and social development of learners" (RSA DoE 2008b:3).

For admission to degree studies at a university, learners must achieve 50% in four subjects from a designated list of subjects. In 2008, 20.2% of the candidates fulfilled admission requirements to under-graduate programmes in Higher Education. A further 23.3% qualified for diploma studies and 19.2% for studies in higher certificate programmes. A total of 334 167 (62.7%) learners therefore qualified for further studies.

A disconcerting issue is the fact that there was a significant drop in the number of learners who entered the final examination. In 2007, there were 920 716 learners recorded to be in Grade 11, of which only 533 561 (58%) entered Grade 12 in 2008. This learner drop-out of 42% (384 155) raised questions in the media and in forums where key stakeholders were present – no reasons could be found. Cronjé (SAIRR: 2009a) declares that some learners could possibly have entered Further Education and Training (FET) colleges after Grade 11, while others might have chosen to repeat Grade 11.

**Table 2.5** ***Grade 12 Performance in Key Subjects in 2008***
(Adapted from RSA DoE 2008b:13)

| Subject | Wrote | Passed at 30% | Passed at 40% | Passed at 50% |
|---|---|---|---|---|
| English 1st Additional Language | 464 179 | 111 487 | 327 335 (70.5%) | 24 998 (5.4%) |
| Mathematics | 298 821 | 106 128 | 136 515 (30.0%) | 56 178 (18.8%) |
| Physical Science | 218 156 | 57 293 | 62 530 (28.7%) | 98 060 (44.9%) |
| Life Sciences | 29 417 | 91 920 | 117 787 (39.6%) | 87 583 (29.5%) |
| Geography | 213 369 | 84 030 | 87 308 (40.9%) | 41 864 (19.6%) |
| Accounting | 176 078 | 52 935 | 55 164 (31.3%) | 67 848 (38.5%) |
| Mathematical Literacy | 263 464 | | 207 230 (79.6%) | 56 234 (21.3%) |

In Table 2.5, the results in key subjects of the Grade 12-examinations in 2008 are tabled (RSA DoE 2008b:13). The total number of candidates who wrote the examination is provided, with an indication of the number who passed and failed the various subjects. The low pass rate for Physical Science and Life Sciences (formerly known as Biology) is pertinent for this study. The pass rates correspond well with each other (ranging from 30% to 50%) and indicate that English as the first additional language produced more satisfactory results (70.5%) than the other subjects. The Mathematical Literacy pass rate was also high (79.6%). This investigation will focus on the Mathematics results, which will be discussed subsequently. The failure rate in the other subjects, excluding Mathematical Literacy and English, ranges from 19% to 45%, and this should prompt further investigation.

After the announcement of the 2008 Grade 12-results, many specialists commented on the performance of this first group in the new system. The Mail and Guardian (23-30 December 2008b:25) argued that in the previous system, many learners who did in fact register on Standard Grade (SG) should have been registered and would have passed on the Higher Grade (HG). However, learners probably registered for Standard Grade in order to achieve better. Therefore the number of learners writing the National Senior Certificate reflects those numbers.

Other reasons, according to the DoE, were the fact that an increased number of learners were issued with textbooks, and many other interventions were successful. Jansen (in Beeld 9 January 2008a:2), expressed concern that comparisons were made as if all learners had had equal opportunities. He referred to the inequalities between township learners and more privileged learners in private schools, where laboratories, internet facilities, well qualified and dedicated teachers were well resourced. Vijat Reddy (Rapport 25 September 2008:3), representing the National Research Foundation (NRF), expressed concern that the "ravine" between the excellent and weak schools had increased even more.

#### *2.6.1.2 An analysis of Grade 12-achievement in South African secondary school Mathematics and Physical Science*

In Table 2.6, an analysis of the 2006 to 2009 Grade 12-results of specifically Mathematics and Physical Science can be found. The table shows the number of learners who passed Mathematics Higher Grade in 2006 and 2007, in order to present a comparative picture. Similarly, the Physical Science Higher Grade results for 2006 and 2007 are also reflected, together with the 2008 and 2009 figures.

**Table 2.6** ***An Analysis of the NSC Grade 12 Mathematics and Physical Science Results in 2006 to 2009***

(Adapted from SAIRR: 2009b and Volmink: 2010)

| Subject | Year (level) | Wrote | Passed at 30% | Passed at 40% | Passed at 50% | Passed at 60% |
|---|---|---|---|---|---|---|
| **Mathematics** | 2006 *(HG)* | 318 000 | | 25 000 | | |
| | 2007 *(HG)* | 348 000 | | 25 000 | | |
| | 2008* | 298 821 | 136 503 | 89 788 | 63 038 | 42 323 |
| | 2009* | 290 630 | 133 789 | 85 491 | 52 866 | 31 786 |
| **Physical Science** | 2006 *(HG)* | 69 302 | | 29 781 | | |
| | 2007 *(HG)* | 71 172 | | 28 122 | | |
| | 2008* | 217 300 | 119 206 | 61 480 | 32 524 | 16 620 |
| | 2009* | 220 957 | 81 507 | 45 531 | 22 329 | 10 308 |

* NSC results (no differentiation in levels)

Brombacher (2004:1) and Volmink (2010) report that from 2001 to 2007, the average Higher Grade pass for Mathematics ranged between 6.7% and 7.6%. The total number of students who passed Mathematics at the equivalent level in 2008 and 2009 was 19.8% and 15.8% respectively. This increase in passes enabled more learners to access programmes where Mathematics was a requirement. A similar trend was observable in Physical Science where, from 2001 to 2007, the average Higher Grade pass was 8.4%. The number of learners who passed at the equivalent level during 2008 and 2009 was 9.8% and 6.7% respectively.

The Senior Certificate (SC) (previous curriculum) was the South African public examination and in existence since 1975 (DoE: 2008b). Candidates could choose between Higher Grade (indicating access to Higher Education) and Standard Grade. According to Figure 2.11, it should be noted that in the years 2001 to 2007, an average of 7% of learners passed Mathematics (Higher Grade). Although the number of learners who passed Standard Grade is not indicated, 32% passed from 2001 to 2007. Together, these two groups compare well with the 136 515 candidates who passed Mathematics in 2008 and 2009, the only difference being that prior to 2008, only 7% would have qualified for undergraduate studies, but 16% qualified nonetheless.

Figure 2.11 also indicates that during the years 2001 to 2007, an average of 9% of candidates passed Physical Science (Higher Grade), with (although not indicated) another 23% passing Standard Grade. Together, these two groups comprised 109 300 learners, and in comparison with the 7% who passed Physical Science in 2008, there is a dramatic decrease in the total number of candidates who passed in the last two years. However, the number of learners who passed the NSC Physical Science (33 543) compares better with the number of learners who passed in the Higher Grade previously (28 500). The quality will probably be different due to new content and a lack of qualified teachers.

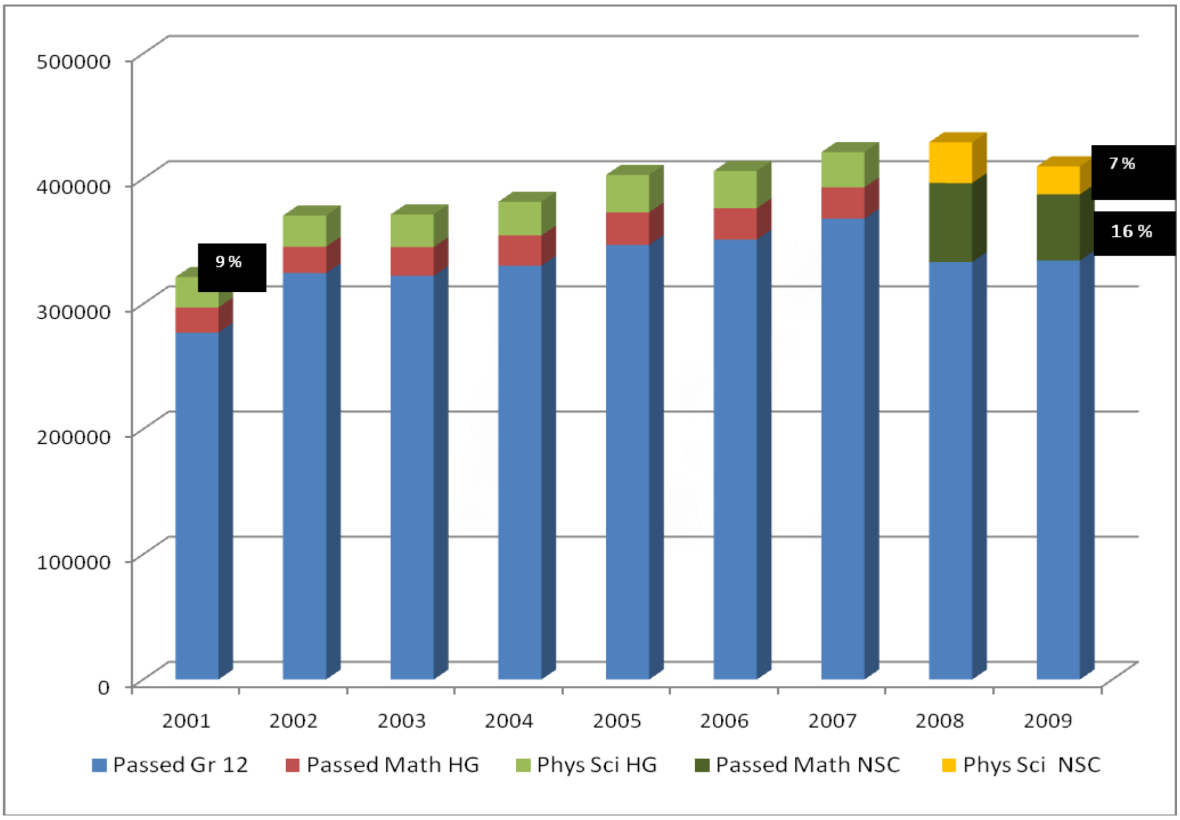


***Figure 2.11*** **Grade 12-results in Mathematics and Physical Science (2001 to 2009)**
(Adapted from Brombacher 2004:1; RSA DoE: 2007 and Volmink:2010)

The above statistics indicate a smaller number of qualified learners to form a pool of potential students for SET, as both Mathematics and Physical Science are usually required for studies in

Science. Many of the students who passed Mathematics will also continue studies in Commerce and other fields of study.

Cronjé (SAIRR 2008a:1) critisises the Minister of Education and compares the current results to that of Bantu education (in the apartheid era). This is a national concern, but even more profound for the Sciences, as approximately 13 000 students (who have passed Mathematics) will enroll in Business, Commerce and Management programmes annually. Another 4 000 students could register for studies in Law and 2 500 in Engineering. If 4 000 students then register for Health Sciences, this would leave only 10 000 students in Natural Science nationally (divided among 21 universities). The following Table 2.7 provides figures that have been published by SAIRR (2008a:1) to project the expected range of students enrolling in graduate programmes in the period 2008 to 2010.

**Table 2.7** ***Higher Education Output Racial Distribution Projections***
(Adapted from SAIRR 2008a:1)

| Field | Coloured | Indian | White | Black |
|---|---|---|---|---|
| Business, Commerce and Management | 1 000 | 2 000 | 7 000 | 4 000 |
| Law | 200 | 300 | 2 000 | 1 500 |
| Engineering | 100 | 300 | 1 500 | 600 |

According to Table 2.7, White graduates will continue to dominate the country's professional sector, at least for 2010, and this will create an even greater imbalance for the Black Economic Empowerment (BEE) sector and affirmative action provisions (cf. Section 2.3). The Science field has even fewer students to select from, let alone achieve transformation targets. The shortage of students relates directly to the shortage of qualified and dedicated Mathematics and Physical Science teachers. Minister Pandor (2008) remarked that good teachers create a pool of potential scientists for South Africa.

In a reply to questions in the National Assembly in Parliament in May 2008, the Minister of Education declared that 814 schools (i.e. 18% of all schools) that offered Physical Science reported a shortfall in laboratory equipment for (RSA DoE 2008b). The Minister (Pandor 2008) elaborated on the condition of the almost 30 000 schools in the country by mentioning that there was a shortage of 6 000 Mathematics teachers and that the DoE had employed 296 foreign teachers.

#### *2.6.1.3 The NCS Mathematics curriculum*

This section will briefly review the National Curriculum Statement (NCS) for Mathematics in Grade 12 to substantiate why students find it problematic to be successful in Higher Education. In an address by Prof. Volmink (2010) he reiterated the nine principles of the National Curriculum Statement (NCS). The following five principles bear relevance when reviewing the new curriculum: a) Outcomes-based education; b) Social transformation; c) Higher level knowledge and skills; d) Value of indigenous knowledge systems, and e) Integration and applied competence.

The above principles make no mention of preparing learners for Higher Education. However, the social transformation is visible in the change in the Mathematics curriculum (RSA DoE 2003b:1-93). All learners have had exposure to Mathematics in one form or another. Volmink (2010) states that 620 000 learners were registered for Mathematics in 2009. In Table 2.8, extracts of the newly introduced themes are listed, as well as excluded themes, as compiled by Sproule (2009). Many themes shifted from one grade to another (see inverse functions), and a theme such as absolute value was omitted completely. The inclusion of Financial Mathematics and Probability (RSA DoE 2003b:1-93) prepares students for Analytical Techniques in their first year, and BCom students should also achieve well. However, the depth of discussion of functions, for example, impacts on the skills and competencies of students in fundamental Science programmes. In a summary of the Further Education and Training Mathematics curriculum (NCS), Sproule (2009) provides details to compare the additions as well as omissions in accordance with the previous curriculum.

**Table 2.8** ***Changes in the FET Mathematics Curriculum (NCS)***
(Adapted from Sproule 2009)

| | Newly introduced | Excluded |
|---|---|---|
| **Learning outcome 1: Number and Number relations** | | |
| Grade 10 | • number patterns<br>• converting between fractions and decimals | • rational exponents |
| Grade 11 | • recognising non-real numbers<br>• simple and compound decay | • absolute value |
| Grade 12 | • future and present value annuities<br>• analysing loan options | |
| **Learning outcome 2: Functions and Algebra** | | |
| Grade 10 | • trigonometric functions<br>• exponential functions and equations<br>• mathematical modeling | • circle relation<br>• sum and difference of cubes<br>• literal equations |
| Grade 11 | • Increasing /decreasing functions<br>• mathematical modeling<br>• intuitive understanding of gradient at a point | • nature of roots<br>• absolute value<br>• inverse functions |
| Grade 12 | • increasing /decreasing functions | |
| **Learning outcome 3: Shape, Space and Measurement** | | |
| Grade 10 | • analytical geometry<br>• transformations<br>• history of geometry and trigonometry | • cot, sec and cosec |
| Grade 11 | • similar triangle theorems<br>• analytical geometry<br>• transformations | • circle geometry<br>• concurrency<br>• complex trig identities<br>• trig reciprocal functions<br>• 3-D problems |
| Grade 12 | • transformations<br>• history of geometry and trigonometry | • similar triangles<br>• locus of a point<br>• complex trig identities |
| **Learning outcome 4: Data Handling and Probability** | | |
| Grade 10 | • univariate data<br>• graphic presentation of data<br>• probability | |
| Grade 11 | • interpretation of statistics<br>• investigative project | |
| Grade 12 | • sampling and sample size<br>• bivariate data and probability<br>• normally distributed data | |

A positive element of the National Curriculum Statement is the fact that Analytical Geometry (formerly only covered in Grade 12) now begin in Grade 10. This will result in learners having a good concept of coordinates, as well as of functions and translation, and reflections of functions. The inclusion of financial and statistical problem-solving skills enhances the curriculum and should create open-minded learners, who will be less method-bound than in the past (Kriek 2008). The fact that first-year Mathematics themes have been included (e.g. probability) makes many experienced teachers feel uncomfortable, as they must prepare and be knowledgeable of new and complicated content.

Nevertheless, most of the more challenging computations and typical complicated themes have been omitted (Kriek 2008 and RSA DoE 2003b:1-93). The fact that learners are no longer required to perform formal proofs in either Algebra or Geometry impacts on first-year Mathematics. This also impedes conceptualisation in Physics. The fact that less algebraic skills and insight are required and "Euclidian Geometry" is omitted creates problems with insight into Mathematical methodology and problem-solving. "Ratios and proportions" are also not covered. Chemistry lecturers have reported that this creates problems, and that additional explanations are required.

The above exclusions impact on the Higher Education curriculum in fundamental Sciences, and first-year lecturers therefore must be aware of and review the content of first-year modules. The question arises: How often do the lecturers make assumptions about the school curriculum and the content, depth and quality covered in the school curriculum? The fact that Grade 12-papers enforce less time constraints (150 marks written in three hours, as opposed to the previous norm of 200 marks in three hours) impacts on the preparation of students for Higher Education. The fact that only 40% of examination papers are based on the previous Higher Grade level (Umalusi 2009) also creates problems for learners when entering Higher Education.

The optional third paper in Mathematics (probability and Geometry) has thus far soothed concerned professors as it requires real problem-solving skills and computational methodology (RSA DoE 2003b:24-64). On paper, the structure and standard of this curriculum is sound. However, it seems that not many learners write the paper, and few schools have appropriately trained staff to teach the content of paper three. In 2009, only 759 (2%) of high schools presented the third paper, with only 13.7% of candidates passing this very relevant paper (Volmink 2010).

In South Africa, challenges intrinsic to the "haves" and "have-nots" are also applicable to Mathematics, where learners from poor socio-economic backgrounds might not even have calculators, which would be common stationery for learners from less remote areas.

Mathematics remains a worldwide key to many Higher Education professions and studies. The researcher has had exposure to at-risk students for many years and is of the opinion that Mathematical orientation and preparation for potential students to enter into Higher Education starts from the first day at school. Exposure to teachers, parents and peers develops and moulds the attitude, self-efficacy (cf. Sections 3.4 and 4.7) and a specific learning culture towards any discipline, especially Mathematics. The Higher Education sector admits these students to institutions, assumes that they come prepared, and that "…it is somebody else's job to bridge the gap or provide remediation for the students" (Strydom 1997:14). Another perception is that students must adjust to the course, as the content and methodology have been the same for the past century, and that this will be sufficient for the immediate challenge.

### 2.6.2 An overview of the influence of the secondary school curriculum on university performance

The alarmingly low pass rate of first-year students at universities (Anthony 2000:5; Beeld 20 December 2008d:3; Beeld 21 April 2009c:1; Gupta, Harris and Carrier 2006:98; and Maree, Aldous, Hattingh, Swanepoel & Van der Linde 2006:229) has been discussed widely in Higher Education, the media and industry. Notwithstanding the negative pass rate, there is a substantial need in the labour force for Science, Engineering and Technology (SET) graduates. Eiselen, Strauss and Jonck, (2007:38) and Du Preez, Steyn and Owen (2008:50-52) are but some of the researchers who are concerned about the level of competence in calculus of students in first-year engineering. Students experiencing difficulty with Mathematics exhibit weaknesses in thinking skills and problem-solving.

The 2009 cohort (first-time entering students in Higher Education) in South Africa, was the first "first-year class" that completed the National Senior Certificate (in 2008), and there has been extensive discussion of these results. Maree (2009:272) also indicates a 10% to 20% drop in Mathematics achievement of first-year students at university level. Studies conducted by Engelbrecht *et al.* (2009:289) emphasise a major difference between the level of school Mathematics and experience at Higher Education level.

Engelbrecht *et al.* (2009:289) traced the academic achievement of 924 students of the 2009 cohort in first-year Mathematics at a local university. A similar analysis at another university was conducted with results of 1 028 students (UJ 2009d:12). In both these studies, the number of students entering with Grade 12 Mathematics results above 60% increased dramatically over the past three years. Figure 2.12 provides a graphical representation of Grade 12-results of three first-year student cohorts.

It should be noted that only 2007 and 2008 results of both institutions were accessible. In the graph, the percentage of students with results higher than 70% (in 2009) is significant. In the graph, increased performance of the students of the one university in 2009 is indicative of the overall better achievement in Mathematics (National Curriculum Statement).

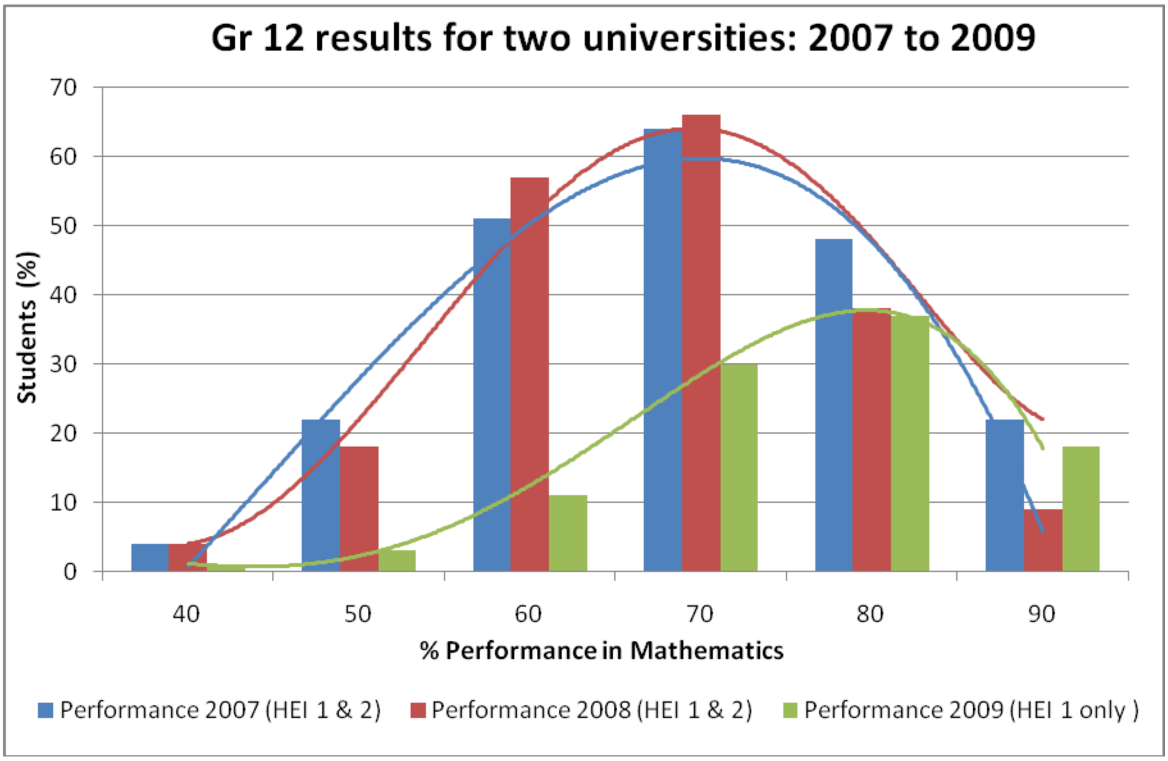


***Figure 2.12*** **Percentage frequency distribution of Grade 12 Mathematics results**
(Adapted from Engelbrecht *et al.* 2009:293 and UJ 2009d:12)

The investigation into the Grade 12-results prompted researchers to measure the results against two other parameters. In a first comparison, Grade 12 final results were compared with the learners' Grade 11-results (submitted with initial application to university). Nel (2009) found substantial grade inflation. Harding (2009:357) is of the opinion that the Grade 12-examination consisted of many examples that learners had done before. The research indicates that considerable discrepancy can be found with students in the lower performance groups. The Grade 12-results of students in the interval 40% to 60% were higher by as much as 21% (5 315 results were compared).

The second comparison was of Grade 12-results with the first university assessment. Engelbrecht *et al.* (2009:294) presents a graphical display of student performance in the 2009 cohort. In Figure 2.13, the shift of the graph to the left (lower performance) is significant (almost a 40% decline).

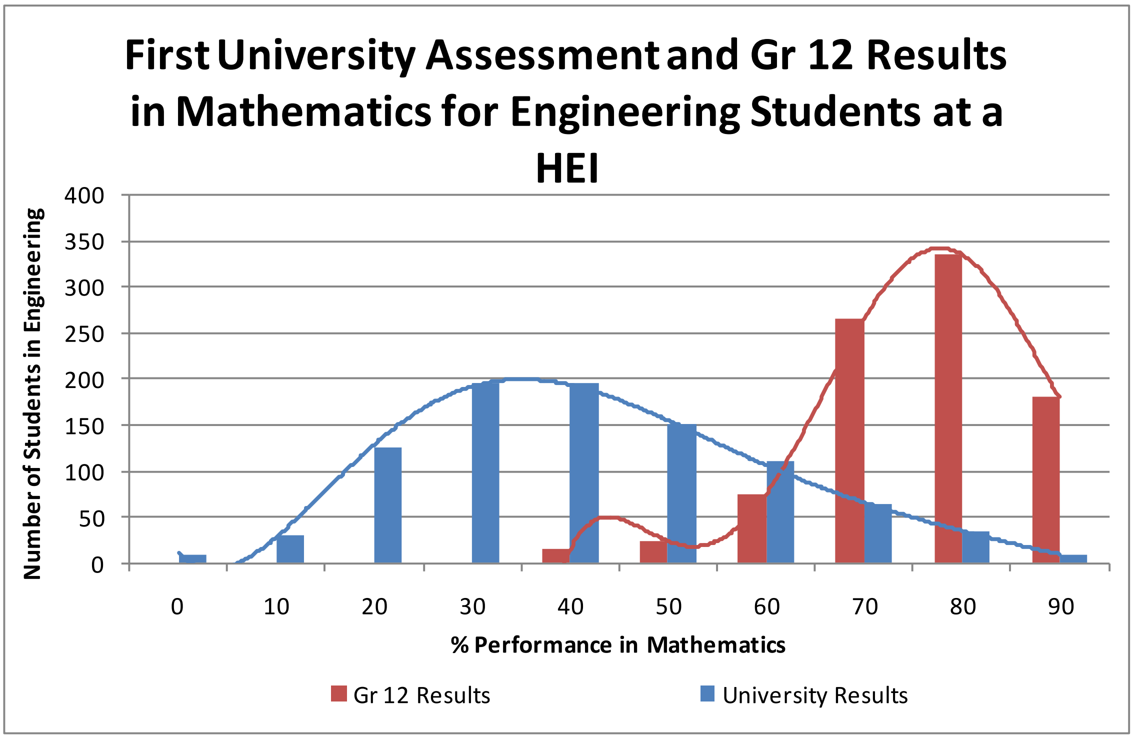


***Figure 2.13*** **Comparison of Grade 12 Mathematics results and first-year Mathematics achievement**
(Adapted from Engelbrecht, Harding and Phiri 2009:294)

The above researchers conducted a survey with experienced first-year lecturers in 2009 (Engelbrecht *et al.* 2009:294-297). Lecturers commented as follows on non-cognitive and cognitive ability of first-year students in the class of 2009:

- In terms of personality: The 2009 cohort was perceived as students with a positive attitude who appeared confident in comparison with previous groups. This confidence could have been created by their achievement in Grade 12 where they achieved good results in Mathematics.
- Lecturers were concerned with the decline in factual knowledge (cf. Bloom's lower order abilities), algebraic manipulation and mathematical formulation (cf. Bloom's higher order abilities).

The research of Engelbrecht *et al.* (2009: 297-299) indicates that there is significant 'weak' correlation between performance in the university test themes and Grade 12-results. This weak correlation of basic factual knowledge supports the perception that Grade 12-results do not reflect this lack in knowledge. Although students performed relatively well in Grade 12, they were not prepared for the level of competence required at university. This could also indicate that they do not put in sufficient effort. However, the achievement does not measure the potential of all students and purely relates to prior knowledge required to pass university Mathematics. Prof. John Volmink, CEO of Umalusi (February 2010), made it clear that the

National Curriculum Statement is not admission to universities, but serves as the end of a school phase.

The lack of content-related skills strengthens the statement that students have not been required to possess basic factual knowledge, even after having passed the subject. The relevant themes indicate a weak correlation, with exponents and logarithms significantly lower. The outcomes-based approach does not require learners to memorise theorems and tables, and problems with Mathematics may start in the foundation phase in primary school. The implication of this lack in a strong theoretical grounding precipitates at higher levels when students experience problems when performing manipulations. Exponents and logarithms rely on applying the laws – which they have to know via rote learning.

Science lecturers usually rely on students' prior knowledge and expect them to know and understand the content (as in previous years). The university lecturer therefore usually continues lecturing as if the fundamental concepts were well embedded at school. This starting level urges a review of previous lecturing practices (cf. Section 4.8). In order to provide new generation students with the required fundamentals, a re-allocation of time and work volume must be done.

From the researcher's observation it seems that university lecturers at all universities have been complaining about the schooling and readiness of students for many years. The 2009 results highlighted more problems than ever before (cf. media statements below). It seems obvious that the schooling system does not prepare students for the demands of Higher Education (Umalusi 2009:20). Lecturers no longer have the 'luxury' of beginning where the schools left off. They are obliged to become real 'teachers'. Many well qualified staff is esteemed researchers but have no formal educational qualifications.

The above problem has been published, with newspapers and electronic media making harsh statements since 2003. The following comments express concern about the quality and standards of teaching and the integrity of results and should sound an alarm for the Higher Education sector:

- South Africa will suffer due to matric fraud (Beeld 31 December 2003:8): Prof. Jonathan Jansen accuses the government of adjusting pass results of Grade 12-learners without enhancing the quality of teaching.
- "Matric quick-fixes miss the mark" (The Star 05 January 2004:3): This report is concerned with the performance level in the Grade 12-examinations, which was lower than before.

- "Dumb and dumber - meet the class of 2006" (Sunday Tribune 18 June 2006:25): Jansen comments on the TIMSS report where South Africa was placed last out of 50 participating countries.
- "Shock Maths, Science lag" (The Star 10 March 2007:25): Inadequate progress in Mathematics and Science challenges is labelled as the biggest constraint to Black advancement.
- Mathematics crisis in South Africa: Ebersohn (Beeld 03 February 2008b:13) is concerned that only 15% of Grade 12-learners were registered for Higher Grade Mathematics in 2007.
- South Africa teaching in crisis (Beeld 13 August 2008c:14): It will take another 30 to 40 years before a well qualified community will be able to serve the economy and labour market in South Africa. Less than 7% of all the Grade 12-learners passed Mathematics in 2007.
- Specialists lead a R30 million project to improve Mathematics results in schools (Beeld 04 May 2009e:13): Two concerned professors were appointed (by provincial authorities) in March in 2009, to make a difference in schools and teacher training in Mathematics.
- Doubt over matric Maths results (Beeld 15 January 2009a:3): The Engineering industry questions the credibility of matric Mathematics results. They are concerned that students' comprehension and results do not compare, as it seems that Grade 12-results are much better in 2008 than mid-year results at school level in 2007. This definitely indicates a better ability than is found to be the case when measured at the first year of Higher Education at institutions.
- Only 17% of students pass Chemistry in first test at university (Beeld 09 April 2009c:1): The manipulation of the National Senior Certificate results had troubled specialists when released and proved to be a concern when students in first-year programmes began experiencing problems.
- "What is the real matric pass rate?" (SAIIR 2009b): The argument states that only 20.2% of the 533 561 Grade 12-learners attained sufficient marks to enter under-graduate study.

### 2.6.3 The progress from school to Higher Education

In 1997, Strydom (1997:8) claimed that the "… new unitary school system will not in the foreseeable future (five to 10 years) produce a school-leaving cohort adequately prepared for higher education." This creates difficulty in attempting to achieve policy aims of redress and equity as prescribed (cf. Section 2.1). The reasons cited include that the mismatch will be acute in the number of well prepared Black students, who will be fewer than required in Higher Education. The number of school leavers with adequate preparation for Higher Education in key scientific and other fields will also be fewer than planned. Scott (2007:2) also reiterates that it is evident that the school sector will not be able to improve outcomes. Further claims include the extremely low intake levels of students entering the Higher Education sector: “We have a third-world schooling and further education and training system and a first world Higher Education system with some variations” (Scott 2007:2). This presents a major gap to be bridged, specifically in Sciences, where content at Higher Education level builds directly on concepts, principles and foundations embedded at school level.

Figure 2.14 (adapted from Strydom 1997:14) presents the vicious cycle of “…an inadequate teaching force producing poorly prepared students…” with the biggest problem being the gap between school and Higher Education.

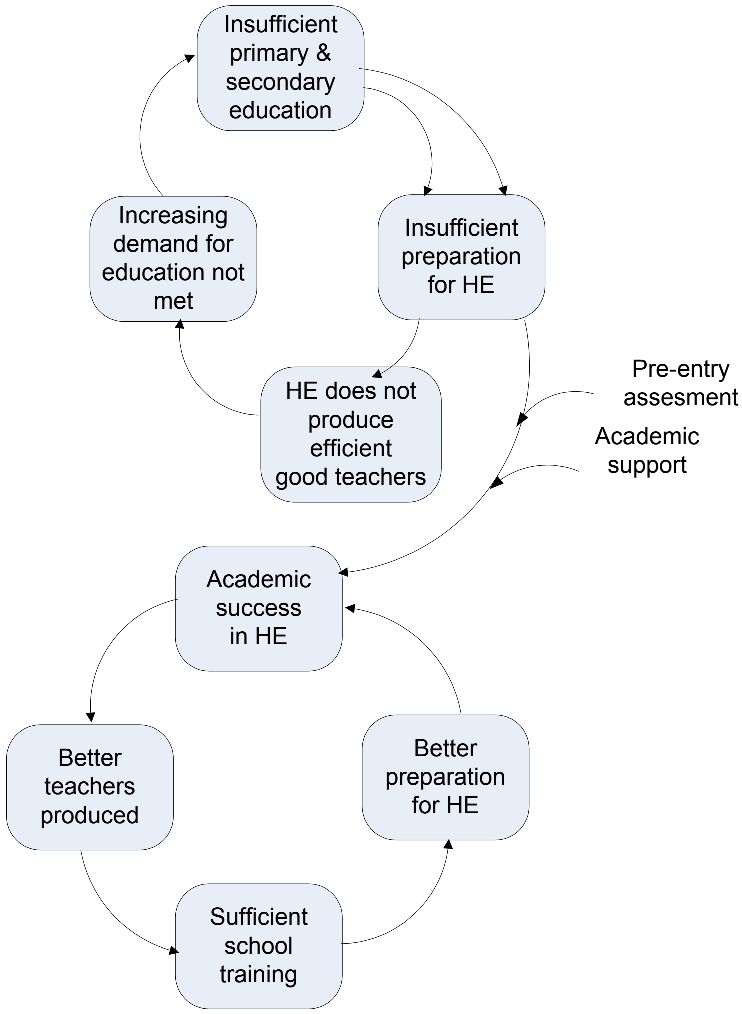


***Figure 2.14*** **The gap in articulation from school to Higher Education**
(Adapted from Strydom 1997:8)

Poorly prepared students (insufficient primary and secondary education) enter Higher Education. With insufficient “reactants” the preparation of qualified teachers results in a greater demand and the even greater gap from school to Higher Education. Two interventions are proposed by Strydom (1997:14) to bridge the gap at primary and secondary school level: i) an urgent review of teacher training and, ii) in this case, the quality and numbers of Mathematics and Science teachers. Review of training does not fall in the scope of this study, but should be further investigated. The second intervention is already taking place, namely pre-entry, bridging and academic support development courses. This will be addressed in detail in Chapter 4.

The above figure indicates the insufficient school preparation of students to be provided to the Higher Education sector. Apart from the impact on extended studies in Science, there is an inadequate provision of good teachers. This cycle is prolonged by deficient school preparation feeding into Higher Education. The model proposes two interventions to be made when students have already been admitted into Higher Education. Firstly, a pre-entry assessment must be performed, and areas to be attended to must be identified. Secondly, provision of appropriate academic support will result in academic success and appropriate preparation of teachers to teach potential students. It is hoped that the once insufficient and dysfunctional school phase can be transformed into effective and efficient preparation of learners, and that qualified and confident teachers will be "polishing" potential graduates.

According to the South African Institute of Race Relations (SAIRR) (2009b:2), the DoE is misleading learners by those with minimum requirements (discussed above) to enrol at universities. The Institute also claims that the very low entry requirements do not reflect the competency level required for successful Higher Education studies (SAIRR 2009b). The South African industrial economy will therefore not be successful if the DoE impedes youth development, especially the Black matriculants. The standard of the Grade 12-examination has been discussed in many forums, as the Higher Education sector needs to blame something for their inability to achieve 100% throughput for badly prepared students. South Africa finds itself in the last position when compared with 50 other countries in the latest international Mathematics and Science studies (Jansen 2007:91). Universities also complain that, although students achieve the correct school grades, they lack the requisite knowledge and skills to "…meet the intellectual demands of the Higher Education environment" (Jansen 2006:1).

In the University of Johannesburg (2008a) it is reported that students entering Higher Education in South Africa allegedly lack foundational skills (reading, writing and speaking) as well as basic numeracy (simple computations, interpreting graphs and computer literacy). Jansen (2006:1) adds that students have been found to have a short supply of "attitudinal attributes" (persistence, confidence, discipline, integrity, determination and perseverance). An analysis showed that South African learners are able to memorise meaningless knowledge, regurgitate archaic formulas and disconnected historical events and cram for examinations. Jansen calls this the "…dumbing down of young people in the educational system…" It is a well known that this charade is played out in South Africa when Grade 12-results are released, with newspapers, media, principals and parents all putting pressurising learners to play the primary roles – to perform to this overwhelming attention. Jansen doubts the quality of these results.

In a survey conducted on school systems (SAIRR 2008a:383; Jansen 2007:1), the placement of South Africa as 50$^{th}$ out of 50 countries in terms of quality, participation rate, completion rate and level of competency, is alarming. Although the number of learners in the system increases, the number passing Mathematics and Physical Sciences remains fairly steady. The same survey also revealed the low throughput rate in Higher Education, indicating that, of the class that enrolled in 2000, only 22% graduated, and only 50% did not drop out before completing the programme successfully – even if it took six years to complete a three-year qualification (compare Table 2.3 p36).

In comparison with Tables 2.5 and 2.6 (p.41 and p.47 respectively), the 2008 Grade 12-achievement resulted in mixed commentary from specialists. According to Mellet (in Beeld 27 December 2008e:2), the problems in schools may be caused by:

- a lack of discipline and bad learner attitudes (also addressed in the Mail and Guardian 23-30 December 2008:25);
- an absence of a strong *culture of learning* in South Africa;
- the low morale of teachers and lack of leadership in schools;
- the increasing learner : teacher ratio;
- the poor training of teachers (cf. Figure 2.14, p.73);
- few resources and little support for learners and teachers;
- financial constraints;
- too much paperwork in the Outcomes-Based Education (OBE) system;
- curriculum and textbooks not being aligned to assessment; and
- the striking of teachers who are union members.

According to the Mail & Guardian (2-9 October 2008a:15) Grade 12-results indicate that the inequalities of the past still exist, and that learners in well resourced schools can adapt better to the OBE programme. The overall academic achievement in schools dropped in the past three years, with 20% more schools achieving less than a 60% pass rate (Mail & Guardian 23-30 December 2008:25). Students entering Higher Education qualify for entry based on their Grade 12-results and meet the admission requirements set by the various universities programmes. The number of students “walking in” after the final Grade 12-results have been released, is a sure sign that many did not initially qualify in the last part of their Grade 12-year (Beeld: 05 May 2009f:13). However, with adjustments, or rather “mark inflation”, more students meet the minimum requirements of institutions. According to O'Connell (Mail and Guardian 23-30 December 2008:25), many matriculants arrive at universities with poor cognitive skills and subsequently battle to cope with academic challenges. Such students are funded by the government and parents (cf. Table 2.2 p.35).

### 2.6.4 Funding as a challenge for Higher Education

The NPHE (RSA DoE 2001a) emphasises the need to recruit students for SET and the DoE will fund institutions for providing more graduates in Science fields. The South African government expressed their concern with the low number of students in the SET environment. According to the DoE (1997b), the following career options are classified under the category of scarce skills: engineers, technicians and scientists. Funds are made available for the establishment of scientific research and innovation (Bawa & Mouton 2002:200) and to "…make Science more responsive to the needs of the majority." The NPHE (RSA DoE 2001a:15) refers to the "… endemic shortage in South Africa of high level professional and managerial skills" and remarks that the major constraint for increasing SET enrolments is the "paucity of matriculants who have required proficiency in Mathematics" (RSA DoE 2001a:18).

## 2.7 SYNTHESIS

This chapter reviewed the changes in the South African Higher Education landscape from 1994. The identification of some of the relevant policies (cf. Section 2.3) that impact on student academic success directly or indirectly reveal different responses. These responses were categorised to establish a basis for a student placement framework in Higher Education Science programmes and fundamental modules (cf. Figure 2.3). The rationale underlying this study was also strengthened by an analysis and synthesis of the drivers of the policies applicable to academic success and Science learning programmes.

In the contextualisation of the policy framework the thrust to bring about transformation was strengthened. The fragmented past must be eradicated and therefore equality, redress and efficiency were enacted by legislation (cf. Section 2.3.2). Educational change is enforced by political and socio-economic related pressures. Among others, the transformation from a fragmented system (based on racial, language and socio-economic lines) towards an equal and fair Higher Education sector was done within the context of merging institutions and the establishment of a new National Qualification Framework in order to acknowledge all types of qualifications in a framework.

A changed approach to teaching and learning (outcomes-based) focuses learners (in schools) and students (in higher education) on developing skills and competencies (cf. Section 2.6). The shift from "knowing" to "to be able to" implies that learners and students are equipped with workplace skills and exposure to information technology. However, many teachers are not appropriately trained and qualified to prepare learners for university studies (cf. Section 2.6).

The National Curriculum Statement states that it was designed to bring about social transformation and not to equip students for university studies. Although the potential of students who enter universities is similar to that of previous groups, the quality of prior knowledge is different, and universities are confronted with this problem continuously (cf. Section 2.3). The broadening of access to accommodate more Black and female students implies that universities can no longer flourish with 'elite' and small student groups. Language and cultural diversity forces universities to transform curricula that had not changed for decades (cf. Section 2.6). Access policies changed the student profile and quality of teaching and learning. Students from dysfunctional schools can enter Higher Education more easily. The lack of resources, qualified teachers, career counselling and financial support, however, impact on Higher Education and challenge institutions to remain competitive in the global market (cf. Section 2.5).

Student success demands that universities should accept the responsibility to support and develop student potential. The schooling system and conditions will not change in the near future (cf. Section 2.6). Management of enrolment (from admission to graduation) and management of students and processes have been indicated as an integral institutional responsibility (cf. Section 2.4). Quality assurance, specifically of learning programmes (cf. Section 2.5), has relevance when various institutions all compete for the same students (from a limited pool) and funding (cf. Sections 2.3 and 2.6). At the same time, the government has been forcing institutions to provide more graduates in the minimum time to ensure maximum funding (cf. Section 2.3).

The financial drive provided by increased government subsidies for Sciences exerts more pressure on institutions (cf. Section 2.3). Fundamental Science modules (in the first year of Higher Education) have been enjoying the 'luxury' of continuing with content and skills previously provided at school level. However, the National Curriculum Statement currently necessitates a redesign of the first-year curriculum (cf. Section 2.6). Changes in Higher Education impact on the entire country while the expensive training of scientists implicates a responsive and responsible review of enrolment strategies and procedures.

Placement of the 'right' students in the 'most suitable' programme should support them to achieve academic success (cf. Section 2.6). More homogenous groups will ensure that academic development is pitched at the appropriate level.

The following factors should be considered when developing a framework for placement of students. The first factor is the limited pool of SET students (cf. Section 2.3). In the second instance the greater participation of Black students (with English as a second language) and females is imperative (cf. Section 2.3). Thirdly, there is a national thrust to increase graduates in scarce skills programmes (cf. Section 2.3). The fourth factor is the enrolment from recruitment to admission and through to graduation, that needs to be managed carefully (cf. Section 2.4). The quality systems in Higher Education demand that programmes shall enhance student success (cf. Section 2.5). Finally the additional time with a structured programme may enhance institutions throughput rate (cf. Section 2.6).

In considering all of above, the opinion of the researcher remains that institutions and systems may achieve optimally but yet not realise student success. Even students coming from highly rated schools and having had a supportive academic learning environment at home sometimes fail at university. Individual differences among human beings eventually determine achievement in different ways. The next chapter provides a literature review of the cognitive, and more specifically, general mental and scholastic ability of students.

# CHAPTER 3

## *MENTAL ABILITY AND ACADEMIC ACHIEVEMENT*

### 3.1 INTRODUCTION

The previous chapter reviewed the changes in South African Higher Education systems. The emphasis was on broadening access, with the accompanying challenge of ensuring that academic success is achieved. The discussion extended the debate on challenges Higher Education in South Africa must face in future, such as enrolment management and quality of learning programmes. Studies in Mathematics and Science learning programmes were emphasised.

In this chapter, the discussion will focus on the cognitive abilities of students in Science programmes. The researcher believes that suitable placement of students in learning programmes (in which they study, will be successful, and the institution therefore will receive increased funding) will depend on matching the ability of the individual to the programme requirements. Chapter four will elaborate on non-cognitive attributes influencing student achievement in the first year of study in Science.

| 3.3<br>THE CHC MODEL OF THE STRUCTURE OF MENTAL ABILITY | 3.4<br>THE LINK BETWEEN GENERAL MENTAL ABILITY AND ACADEMIC ACHIEVEMENT | 3.5<br>GENERAL MENTAL ABILITY AND ACHIEVEMENT TESTING |
|---|---|---|
| **3.3.1 Conceptualisation**<br>3.3.1.1 Ability<br>3.3.1.2 Intelligence<br>3.3.1.3 Mental ability<br>3.3.1.4 Aptitude<br>3.3.1.5 Proficiency<br>**3.3.2 The structure of mental abilities**<br>**3.3.3 General mental ability and the *g*-factor**<br>**3.3.4 General mental ability and intelligence testing**<br>**3.3.5 Relevance of general mental ability for a model of student placement**<br>**3.3.6 General mental ability and levels of thinking** | **3.4.1 Mental ability and education in Mathematics**<br>**3.4.2 Mental ability and Science education**<br>**3.4.3 Mathematics and Science preparedness for HE** | **3.5.1 International trends in achievement testing**<br>**3.5.2 National trends**<br>**3.5.3 Admission and placement testing** |

***Figure 3.1*** **Structure and relation between mental ability and academic achievement**

In Figure 3.1 the researcher provides a schematic presentation of the outline of the chapter. The flow of the investigation commences with a structure of general mental ability, followed by an investigation of the link between general mental ability and academic achievement. Finally, achievement tests are reviewed, in order to perform successful placement. In Figure 3.1, the arrow narrows to the right from generic forms of general mental ability to the application in Science and related contexts.

The following section will outline the rationale for including the influence of general mental ability on academic achievement in this study.

## 3.2 RATIONALE UNDERLYING THIS CHAPTER

The literature study in this chapter focuses on the role of general mental ability and cognitive preparedness in student academic achievement in gateway Science programmes. The three fundamental Science disciplines form the core of most curricula in Science and therefore, this investigation focuses on Mathematics, Physics and Chemistry at first-year level.

Firstly, the chapter identifies concepts and analyses various representations of the concept "general mental ability". Subsequently, the focus moves to the structure of mental ability and to the development of a framework towards optimal placement of students in Higher Education Science programmes (and modules), in order to promote academic success.

Secondly, the purpose is to contextualise general mental ability, the g-factor, intelligence and intelligence testing, by focusing specifically on available literature by John Carroll. Cognitive ability, as presented in the structure of the Cattell-Horn-Carroll (CHC) model, will be the framework for investigating ability levels. A comparison of the hierarchical model of abilities (CHC) and the cognitive thinking model in the taxonomy of Bloom guides the investigation of achievement testing.

Thirdly, a further contextualisation of the abovementioned literature findings will focus on the academic achievement of university students in gateway Science modules in the South African Higher Education context.

Student selection for Higher Education, based on predicted academic achievement, has been a contentious theme since the early 1900s. Despite debates referring to such testing, the use of scholastic aptitude tests appears to be widespread. In the USA, the Scholastic Aptitude Test (SAT), measuring verbal and mathematical ability, has been used from 1926 (Sattler 2001:136), and is still being applied as standardised admission testing for Higher Education. In South Africa, there appears to be a strong move towards the introduction of so-called National

Benchmark Tests (NBT), to inform universities of the scholastic aptitude and cognitive preparedness of prospective students (HESA 2006:7). None of the current practices for admission applies to Science programmes, although a few programmes (i.e. Medicine, Military programmes and Architecture) have been utilising some tests for admission purposes. The fact that intelligence plays an important role in student achievement will be discussed according to a model of cognitive ability.

## 3.3 THE CATTELL-HORN-CARROLL MODEL OF THE STRUCTURE OF MENTAL ABILITY

To facilitate the discussion of the role of mental (cognitive) ability in academic achievement, the present chapter employs the Cattell-Horn-Carroll (CHC) model of the structure of mental ability as a framework. This model has a major influence and presents the most widely accepted model of the structure of mental ability by differential and educational psychologists (Sattler 2001:136). The discussion highlights the importance of general mental ability - the highest level in the hierarchy of mental abilities - in the prediction of academic achievement.

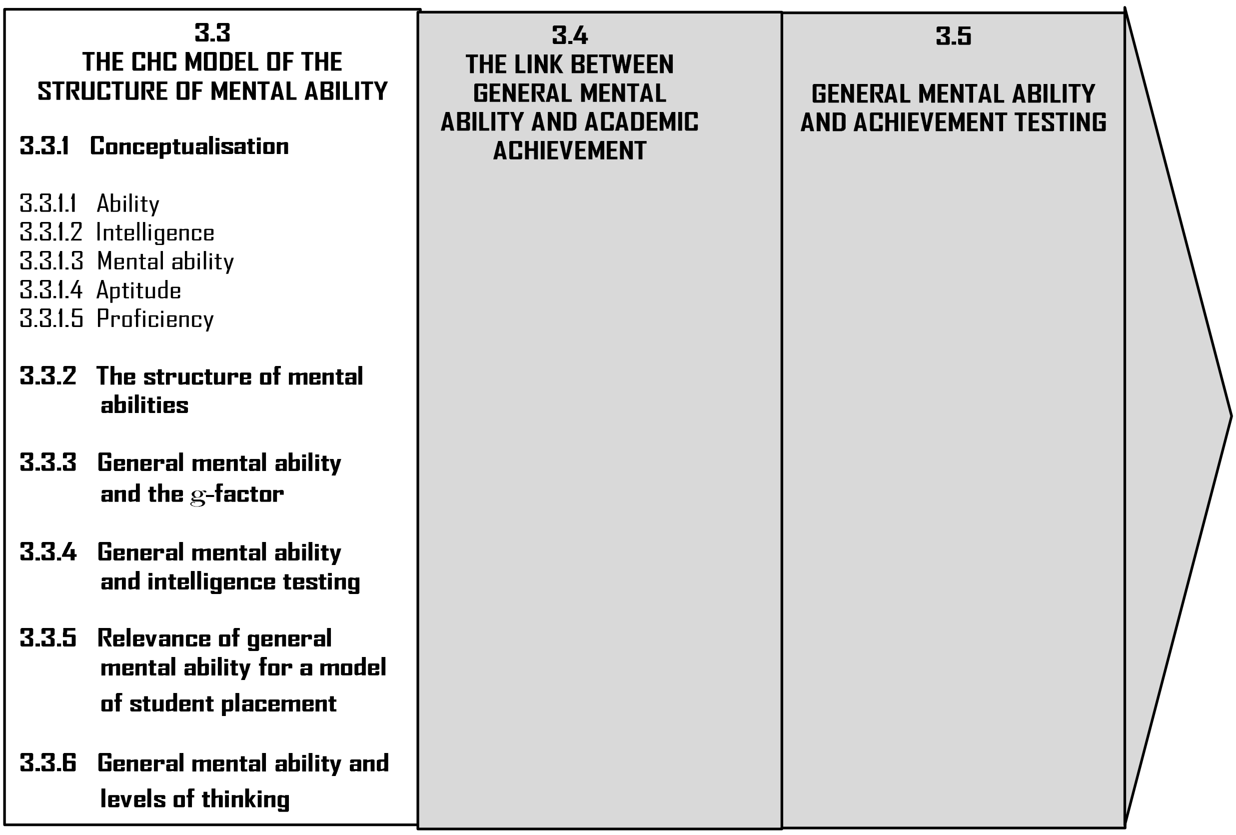


***Figure 3.2*** **The CHC-model of structure for mental ability**

This investigation will not debate competing models of the structure of mental ability, nor focus on different explanations for the development of mental ability. Rather, the chapter focuses on one widely accepted model of the structure of mental ability, namely the CHC-model. The study reflects on the implications this specific model holds for the placement of students in Science-related programmes at universities. Before introducing the CHC-model, it is necessary to define some related concepts and focus on similarities and differences among the concepts.

### 3.3.1 Conceptualisation

The following concepts are commonly found in literature, based on student achievement. However, meanings overlap and, to avoid confusion, the five concepts below need to be more closely examined.

#### *3.3.1.1 Ability*

The word “ability” exemplifies the commonly used word “can”. The Oxford Learner’s Dictionary (2010:2) defines ability as: “…suitableness or adaptation for a purpose; fitness, aptitude, quality in a person or thing which makes an action possible; suitable; proficiency.” For the purpose of this study the most applicable definitions of ability are “A natural faculty; a particular power of the body or mind; a personal talent or skill”, as well as “mental power or capacity, cleverness, astuteness” (Sattler 2001:130).

Ability can be described as a broad concept, including potential and contributed to by personality, motivation and an enabling environment. Carroll (1993:4-9) addresses the link between ability, potential and what is learned from everyday experience. He concludes that if an individual has the potential (possibility or capability to develop in future) to perform, is willing and motivated to perform (personality), and all the conditions are favourable (environment), a specific level of achievement will be possible.

#### *3.3.1.2 Intelligence*

Sattler (2001:136) provides a table with 18 definitions of intelligence, developed over years of research. The earliest definition for intelligence is Binet’s formulation in 1916. In agreement with Eysenck (1998:21), Murphy and Davidshofer (1998:21) point out that intelligence is a construct, rather than a concrete phenomenon, and therefore their definition of intelligence refers to behaviours that serve as indicators of different levels of intelligence. Carroll (1993:37) defines intelligence as “… the degree to which, and the rate at which, people are able to learn, and retain in long-term memory, the learned knowledge and skills from the environment…”

The working definition of intelligence for the purpose of this investigation will be: An ability to learn, to remember and to apply knowledge to the specific environment at a specific point in time.

#### *3.3.1.3 Mental ability*

In performance of any kind, the brain will be actively involved, and therefore any ability will indicate a mental ability. Carroll (1993:10) limits the range of abilities to those specifically involved in "…the processing of mental information." This will therefore include the performance of tasks for uploading and acquiring information, as well as the mental processes of manipulation, retrieval, evaluation and application of that acquired information. Murphy and Davidshofer (1998:23-27) identify mental abilities as verbal comprehension, induction, word fluency, number, spatial relations, associative memory, perceptual speed, and reasoning. The working definition for the purpose of this study will be: An ability to think and apply to various environments.

#### *3.3.1.4 Aptitude*

The Oxford Advanced Learner's Dictionary (2010:61) describes this concept as "…quality of being fit for a purpose; suitableness; appropriateness…". This discussion will adopt the notion of aptitude, as described by Carroll (1993:16) and Murphy and Davidshofer (1998:34), namely: the measure of prediction of future performance, with a prospective purpose. As Murphy and Davidshofer (1998:33) state, aptitude tests are general tests and measure "…cumulative knowledge, skills and abilities…" accumulated in everyday life and through experience. It will be almost impossible to design a test that does not rely upon any prior knowledge or a "one-size-fits-all approach".

#### *3.3.1.5 Proficiency or achievement*

Proficiency or achievement is measured against what has been learned, i.e. prior knowledge, and is reflective rather than predictive, with a retrospective purpose. Achievement tests have been widely used in educational settings (Murphy & Davidshofer 1998:33). Such instruments measure the mastery of specific content as in a school examination or licensing test. Scores also reflect on the amount and quality of schooling, as well as the level of crystallised intelligence (cf. Section 3.3.2), i.e. acquired skills and knowledge (Sattler 2001:140). Proficiency tests measure and predict performance at a broad level, where specific content knowledge is insignificant. For the purpose of this study proficiency will mean: An ability to reflect on and master specific content.

A clear description of each of the above concepts is required for application in this investigation. Ability provides an indication of favourable successful achievement, whereas aptitude indicates future achievement. Intelligence indicates learning ability, while mental ability provides a gauge to the mental processing of information required for learning. Proficiency (or achievement) reflects on prior learning. In order to align the above concepts in this research, the Stellenbosch University (SU) Access Test is used as an example of an instrument to measure proficiency.

### 3.3.2 The structure of mental abilities

Research pertaining to general mental ability (also known as cognitive ability or intelligence) gradually developed from the initial Spearman two-factor theory (1927) to the multi-factor theories of Thorndike and Thurstone (Sattler 2001:139-148). The investigations eventually evolved into a hierarchical theory with different layers or strata (as evidenced in the models of Vernon, Cattell, Horn and Carroll in Sattler 2001:130-156). Raymond Cattell and John Horn (in Sattler 2001:140) distinguish between two types of intelligence, namely fluid intelligence (*Gf)* ("…a nonverbal, relatively cultural-free mental efficiency") and crystallised intelligence (*Gc*) ("…acquired skills and knowledge that are developmentally dependent on exposure to culture").

Carroll (1993:634) acknowledges that the Cattell-Horn presentation of cognitive abilities and the *Gf*-*Gc* model expands beyond the fluid and crystallised intelligence to other general abilities. Horn, Cattell's student, supports the presence of "general abilities", while Carroll proposed a three-stratum model (McGrew 2009:1). The eight general abilities of the second stratum are the two abovementioned abilities of fluid intelligence (*Gf)* and crystallised intelligence (*Gc*), as well as general memory of learning (*Gy*), broad visual perception (*Gv*), broad auditory perception (*Ga*), broad retrieval ability (*Glr*), broad cognitive speediness (*Gs*), reaction time/decision speed (*Gt*) and quantitative knowledge (*Gq*).

According to Carroll (1993:634), the above general abilities moderate specialisation of ability and "…basic constitutional and long-lasting characteristics of individuals that can govern or influence a great variety of behaviors in a given domain". The CHC-theory of intelligence and the Cattell-Horn (G*f*-G*c)* theory are described by McGrew (2009:1) as "…most prominent psychometric theoretical models." Carroll (1993:126) elaborated on the theory developed by Cattell and Horn, and in reviewing 450 studies, extracted common ability factors. The factors are classified into three levels or strata traditionally presented in a pyramid shape.

In Carroll's hierarchical model, more than 60 narrow abilities, such as reading, comprehension, reaction time and memory span, constitute the base of the hierarchy. Narrow abilities constitute Stratum I and represent specific mental abilities. Stratum I collapse into Stratum II, constituted by eight general (broad) abilities (Gf; Gc; Gy; Gv; Ga; Glr; Gs; Gt and Gq). In turn, this layer (Stratum II) collapses into Stratum III, the general mental-ability factor, often referred to as "g" (indicated in Figure 3.3 below).

The structuring of broad abilities implies that the 'ranking' will not be similar across individual cognitive tasks (Murphy & Davidshofer 1998:24). Ranking might imply that some respondents perform better in a range of memory tasks, while others will achieve better in visual perception or cognitive speed. The highest level (Stratum III) constitutes the general factor, the g- factor, conceptually similar to the general mental-ability factor proposed by Spearman. This factor is in the highest stratum, indicating its very general nature. It includes numerous unlisted data sets, yielding a single higher stratum factor. At this level, general mental ability implies stable differences in performance "…on a wide range of cognitively demanding tasks" (Murphy & Davidshofer 1998:24). The classical presentation of the Three Stratum Model was adjusted and is shown in Figure 3.3.

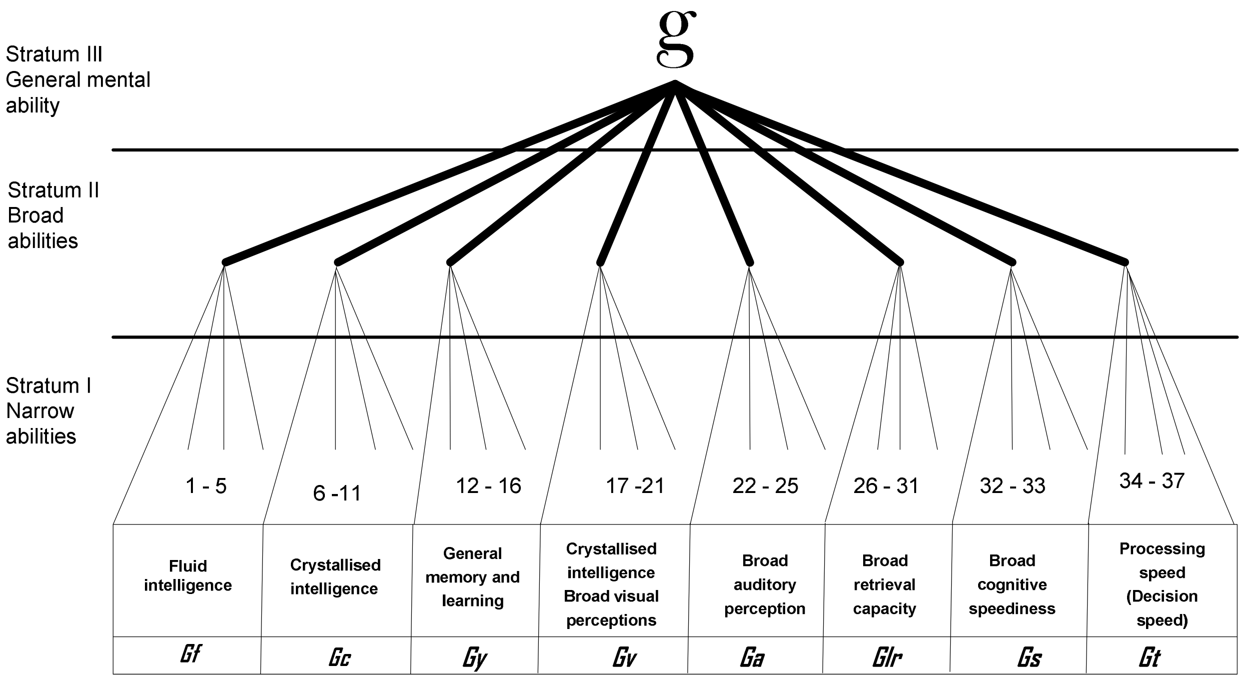


***Figure 3.3*** **The Three Stratum Model of mental abilities**
(Adapted from Carroll 1993:626)

The triangular or pyramid shape (Carroll 1993:626 and Sattler 2001:142) indicates the allocated numbers (1–37), each representing the various narrow abilities under each of the broad abilities below the triangular shape. The narrow abilities coincide with the broad abilities (*Gf – Gt),* all contributing to overarching general mental ability. Carroll's structure presents a hierarchy (subtype-supertype relationship), not a taxonomic classification.

Another presentation of the hierarchical model is illustrated in Figure 3.4, where the researcher designed a diagram indicating the CHC-model with a metaphor of a lens system (cf. Figure 2.4). Although similar information is presented here (cf. Figure 3.3), the structure provides a different perspective on the contribution of various abilities to general mental ability. Specific mental abilities are incident on a convex lens to converge to Stratum II for the broad abilities, which then all converge to the Stratum III general factor, general mental ability. The most prominent broad abilities (Stratum II) for the purpose of this study are fluid intelligence, general memory and learning, broad visual perception, broad cognitive speediness and processing speed. All these abilities are required for gateway Science modules, and are discussed in detail in section 3.5.

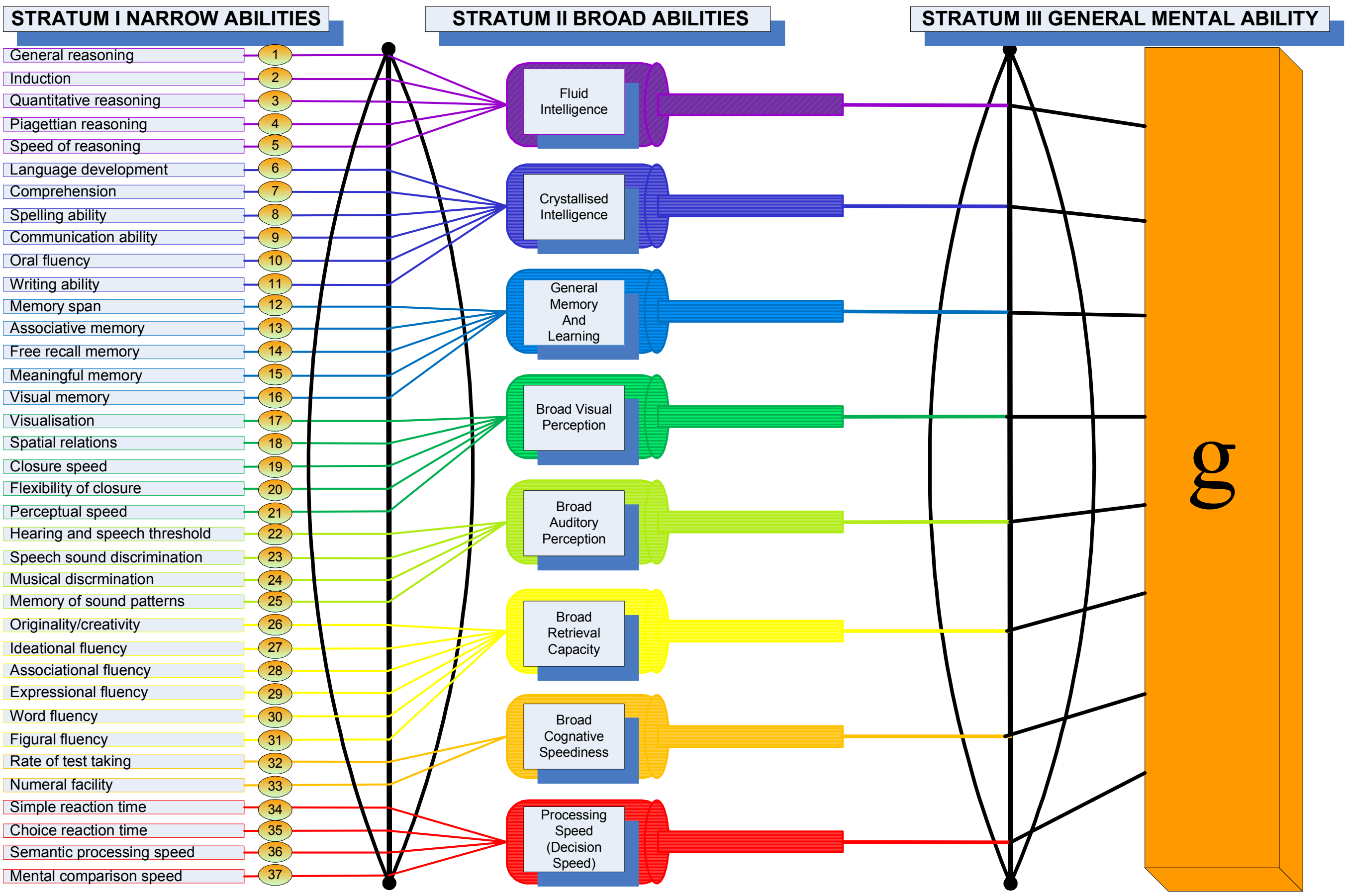


***Figure 3.4*** **A spectrum of mental abilities, as adapted from the CHC-model**
(Adapted from Carroll 1993:626)

Figure 3.4 resembles the spectrum of light, where the various colours in the spectrum converge (come together) to compose white light. The white light represents the general mental-ability factor (Stratum III). In Physics, sunlight will represent the white light, with no distinguishable features in the spectrum. The outer layers of the Sun consist of cooler gases to absorb some light, creating particular wavelengths, which are perceived as different colours (Marion 1976:369-373). The analogy with the general mental ability (g) is fitting, as everybody possesses general mental ability (the rays of the sun shine everywhere), and the environment (outer layers) determines the colour emitted (narrow abilities).

The above views forced psychologists, psychometricians and assessment professionals to develop a "Three Stratum" vision of human cognitive abilities. Highly specific abilities are at a low-level stratum, while narrow abilities are level indicators of mastery at various cognitive levels, for example: general reasoning, communication ability, speech sound discrimination, and numerical ability. The conceptualisation of abilities and skills manifesting in a general factor has occupied researchers for a century. Cognitive abilities can also be described as "mental skills" or "describing the process and results of information-processing." McGrew (2009:1) describes the measurement of mental abilities as one of the milestones of modern psychology.

As observed in Figures 3.3 and 3.4, the abilities represented in Stratum I are mostly composed of abilities that also constitute the various sub-tests, well known in intelligence test batteries, such as vocabulary, sentence completion, number series, matrices, etc. These very narrow, specific abilities enhance achievement, are trainable (Gottfredson 2004c:25), and inter-correlate and culminate in a broad classification, such as verbal, spatial, quantitative and memory abilities. The discussion below will briefly probe general mental ability in Stratum III.

### 3.3.3 General mental ability and the g-factor

Stratum III of the abovementioned structure (Figures 3.3 and 3.4) represents general intelligence or general mental ability. Psychologists spent the past decades attempting to isolate this underlying general factor of general intelligence (abbreviated g-factor) from all other cognitive abilities gauged in mental tests. Identification of the general mental ability factor enabled Spearman (Gottfredson 2004a:174) to reveal a very important fact, namely that general mental ability is common to every type of mental achievement.

Spearman was able to perform a statistical extraction of general mental ability. According to Jensen (1998:170), "…the g-factor reflects whatever it is - presumably some attribute of the brain – that causes individual differences in performance." According to Wittenborn (2004:2), the Spearman factor analysis method "…determines the minimum number of underlying dimensions necessary to explain a pattern of correlations among measurements." Wittenborg conducted tests with many individuals and found that those who scored high in the tests for general mental ability also tested high in individual tests (understanding paragraphs; arithmetic; estimating lengths; etc.). Hence, general mental ability can be regarded as a major building block for all mental abilities and constitutes the basic ability to learn, to reason and to solve problems (Gottfredson 2004a:175). This is crucial for predicting student success.

Gottfredson (2002:29) is of the opinion that individuals with a high g-factor can deal with complexity (learning complex material quickly and efficiently), and possess the ability to avoid cognitive errors. A high g-factor facilitates the ability to process information, and this not only ensures that knowledge is acquired; it creates good understanding and faster learning. Gottfredson (1998:24) postulates that the existence of general mental ability is not merely an abstract concept created by scientists. Even non-professionals can identify somebody as 'smart' or having a 'bright' idea, or presenting a clever solution to a problem. General mental ability (intelligence) can therefore best be defined as "…the ability to deal with cognitive complexity" (Wittenborn 2004:2 and Gottfredson 1998:24). It is general in scope and represents a set of generic thinking skills, including: reasoning well, thinking abstractly, learning quickly and efficiently and solving problems.

To assess the application of general mental ability in real life there must be a scale where cognitive levels can be plotted. It remains true that intelligence, as measured by IQ tests, acts as the single most effective predictor of individual performance at school or in a job recognised in the field of testing (Gottfredson 2008:391). In a description by Jensen (1998:170) the g-factor is the *"…chief active ingredient…"* in the predictive validity in IQ tests.

### 3.3.4 General mental ability and intelligence testing

General mental ability explains most of the differences encountered among individuals in their performance in diverse mental tests (Gottfredson 2004b:35-38). In addition, general mental ability provides a reliable measurable distinction between individuals' cognitive ability, and it is universal. Measuring mental ability puts researchers in a position to distinguish between individuals. Although Spearman initiated the research, Gottfredson (2004b:35-38), together with Jensen (1998:124), Sternberg and Kaufmann (1998:500) and Carroll (1993:30-142), to name but a few, continued investigating this method of expressing intelligence.

Tests measuring specific mental abilities all reflect general mental ability (g) to varying degrees, and can be extracted from the scores of any battery of tests (Carroll 1993:48 and Gottfredson 1998:24). An explanation by Gottfredson (2004b:35) is that the g-factor "…can be distilled from scores on any broad set of cognitive tests." No single test measures general mental ability (g) only. All existing mental tests are in fact 'contaminated' by the effects of specific mental skills.

Carroll (1993:44) adds to this reasoning with another view, namely "…IQ represents the degree to which, and the rate at which, people are able to learn." General mental ability tests (including IQ tests) combine many sub-tests to measure specific cognitive skills, with intelligence testing being inter-changeable. This characteristic indicates that the predicative value of mental tests is deduced from general mental ability rather than from intelligence tests measuring specific aptitudes. Intelligence testing has been standard practice in many countries and is widely applied by educational institutions and practitioners (Wittenborn 2004:3 and Gottfredson 1998:26). Results of such testing have been a gauge of student potential for many years (Gottfredson 1998:25 and Murphy & Davidshofer 1998:33).

Cognitive abilities required to carry out any task – from the easiest to the most complex tasks – are brain-based skills and require mental processing. This investigation will apply general mental ability to analyse the complexity required at different cognitive levels of learning.

### 3.3.5 The relevance of general mental ability for a model of student placement

The preceding discussion provided an overview of the structure of general mental ability and the measurement of mental abilities via intelligence testing. There is a tendency for mental ability levels of individuals to remain consistent from adolescence onward. Gottfredson (1998:29) postulates that there has not been any successful attempt to raise general mental ability. She explains that while all the educational enhancement, dietary plans and adjustment to environments have not been able to make a significant change to general mental ability, focused attention on skills can enhance achievement. The direct link of general mental ability (g) to effective learning will therefore guide the placement of potentially successful students. To learn, to reason, to solve problems and to make decisions are skills that will be required in the workplace (Gottfredson 1998:31 & 2002:27).

The fact that intelligence testing can predict subsequent academic and socio-economic success in life, makes measurement of some form of general mental ability relevant. The important value of general mental ability is based on the fact that it can predict academic performance, job performance and income by means of its broad applicability (Gottfredson 2002:27). General mental ability is stable, independent of measurement instruments and correlates well with higher order thinking skills, and is therefore relevant for the purpose of this study.

Higher order thinking skills (e.g. abstract thinking and problem-solving) are also fundamental in the search for predictors of academic success in Science programmes (cf. Section 3.4.1 and 3.4.2). This section will culminate with the application of general mental ability in thinking skills, with specific reference to Bloom's taxonomy (cf. Section 3.3.6). Performance levels such as comprehension, evaluation and creation will therefore be relevant to determine successful academic achievement in Mathematics and Science programmes.

### 3.3.6 General mental ability and levels of thinking

The study of Jensen (1973:267) on mental processes indicates that, although every individual possesses different general mental abilities, individual differences empower all individuals to apply abilities in a unique personal way. The mental processes that primarily affect achievement were found to be fluid intelligence (*Gf)*, crystallised intelligence (*Gc*), and a memory factor (Jensen 1973:267 and Carroll 1993:634). Achievement will be determined by mental information processing. All the other abilities identified above (cf. Section 3.3.2) are required for optimal functioning. Carroll (1993:634) added general knowledge*,* short-term memory, psychomotor speed, reading and writing, psychomotor abilities, olfactory abilities, tactile abilities and kinesthetic abilities to complement information processing.

The accumulation and input of information will inevitably determine the quality of information processing. In part, the quality will rely on teaching and learning practices involved in collecting and processing information. This research focuses on the cognitive levels of learning, as initially developed by Benjamin Bloom (1956) and reviewed by Anderson and Krathwohl (2001). The inclusion of this taxonomy in this study should link general mental ability to actual learning taking place in a classroom and that is being assessed. Assessment indicates measurement of ability to a certain extent (in reality, measurement of prior learning).

The taxonomy of levels in the cognitive domain focuses on the ways an individual acquires and uses knowledge. In Bloom's taxonomy (Bloom 1956:3), cognitive levels are structured in six ranks "…analyzing the kinds of learning that take place in a class discussion…" Each level represents a different type of cognitive thinking or behaviour, ranging from level one (least complex) and progressing to level six (most complex thinking). Anderson, a student of Bloom, together with Krathwohl, revised the taxonomy in the 1990s (Smythe & Halonen 2005:1 and Biggs & Tang 2007:81). Changes are noticeable in the language, and workable objectives, with nouns replaced by active verbs (cf. Table 3.1).

The South African teaching approach of Outcomes-Based Education (OBE) also refers to this taxonomy in determining levels of outcomes (Geyser in Gravett and Geyser 2004:20-40). According to Bloom (1956:7), the outcomes are related to the complete taxonomy consisting of three major domains: cognitive, affective and psychomotor domains. The underlying principles of Bloom's cognitive model are: *Firstly*, the distinction between classes reflects the distinctions educators make, based on student behaviour. *Secondly*, the taxonomy is developed logically. *Thirdly,* it is consistent and descriptive of every type of educational goal. The taxonomy is structured in a hierarchy, regarded as building on the previous classes and is a useful and effective tool. The description of the levels of the cognitive domain is indicated in Table 3.1.

The table also provides a comparison of the revised Taxonomy with the original taxonomy. In the revised taxonomy, the thinking levels (nouns) are replaced with active verbs.

**Table 3.1** ***A Revised Bloom's Taxonomy of Cognitive Thinking***
(Adapted from Smythe & Halonen 2005:1)

| **Level** | | **Bloom's Taxonomy** | **Revised Taxonomy (Anderson & Krathwohl)** |
|---|---|---|---|
| Lower order skills | | **Thinking level (nouns)** | **Active verbs** |
| ⇩ | 1 | Knowledge | Remember |
| | 2 | Comprehension | Understand |
| | 3 | Application | Apply |
| | 4 | Analysis | Analyse |
| Higher | 5 | Synthesis | Evaluate |
| order skills | 6 | Evaluation | Create |

The replacement by verbs depicts an active thinking process (Smythe & Halonen 2005:1). The first four thinking level nouns are replaced by verbs: *knowledge* is replaced by *remember,* as "…knowledge is an outcome of thinking or a product of thinking, not a form of thinking per se…" and *comprehension* becomes *understand.* At the most complex level, the *evaluation* (Bloom 1956:3) is replaced with *synthesis* which is regarded as a more complex skill. The verbs allocated by Anderson and Krathwohl (Smythe & Halonen 2005:1) are *evaluating* to reflect a specific category of thinking, and *creating.* Creative thinking is regarded as a more complex skill than evaluating, which is critical thinking (Smythe & Halonen 2005:2). It is explained as "…one can be critical without being creative… but creative production requires critical thinking."

The structure of the taxonomy is hierarchical, where each class is regarded as building on previous levels. In another layout (resembling the Carroll hierarchical model), the researcher presents the Bloom hierarchy for the cognitive domain as two triangles (presented in Figure 3.5).

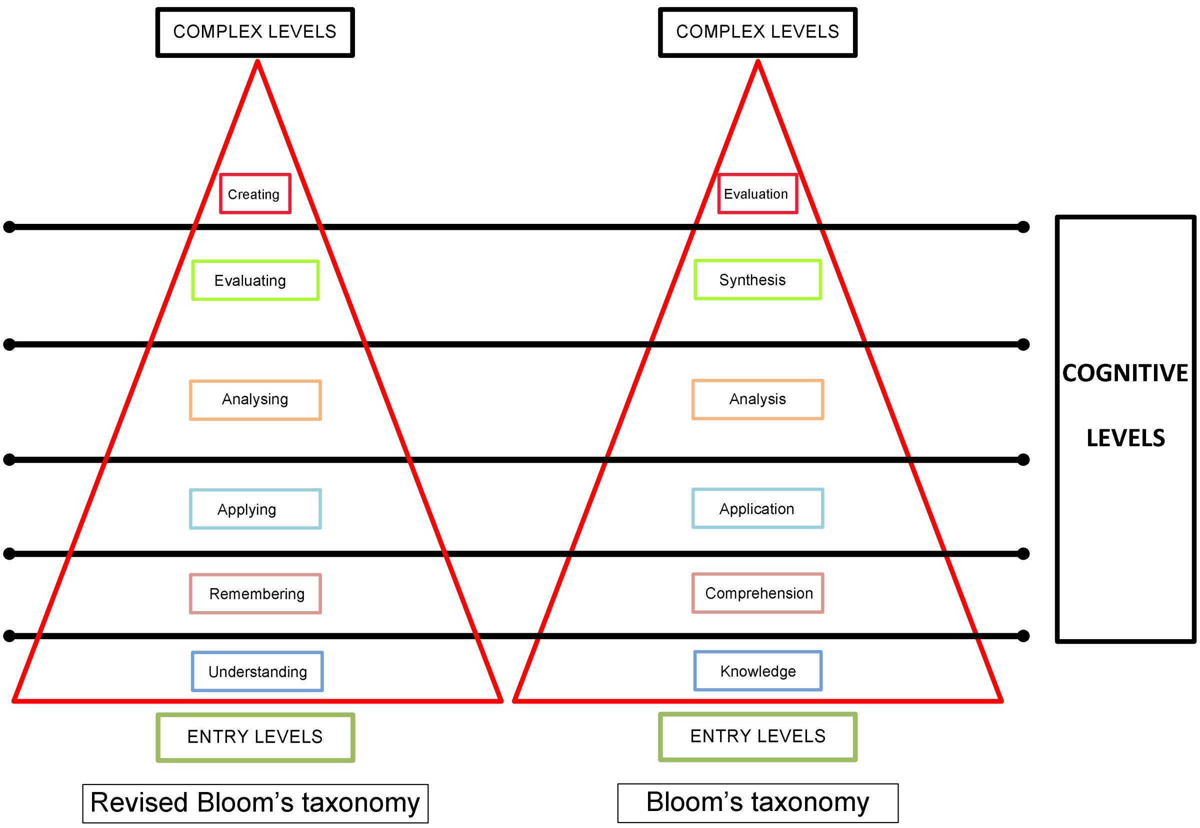


***Figure 3.5*** **Bloom's hierarchical model of cognitive levels**
(Adapted from Cronjé 2006 & Smythe and Halonen 2005)

The structuring of levels of cognitive skills and competence is of great significance in designing teaching and learning activities. In a study of the CHC-model (Carroll 1993:625), the researcher mentions that the model lacks the ability to analyse higher order factors that would correspond with everyday challenges such as "mathematical ability". Mathematical ability relates mostly to higher order cognitive levels (cf. Section 3.3.1) of applying, analysing and evaluating, in Bloom's hierarchy. Mathematics requires diverse cognitive levels, and Carroll (1993:626) reiterates that there cannot be a single mathematical ability. According to the CHC-model, mathematical tasks will require a range of applicable abilities that can be higher order or lower order abilities (cf. Section 3.3). Fluid and crystallised intelligence (*Gf* and *Gc)* (cf. Section 3.3.2) can be higher order abilities, while induction, sequential reasoning, quantitative reasoning and visualisation can all form part of lower order abilities.

The researcher is of the opinion that the South African curriculums for foundation (primary school) as well as senior phases have been adjusted to focus on higher order skills. In informal discussions with teachers and lecturers all agree that rote learning of theory and theorems establish a firm basis for higher order learning to take place. Neglect of the memorisation of tables and simple mathematical procedures creates conceptual problems when learners proceed to higher grades and challenging problem-solving skills. Regarding the rote learning of facts, Pandor (2008:1) is quoted: "Facts and knowledge are important and learners need support from competent and knowledgeable teachers." Carroll (1993:628) explains that the concept of mathematical ability has no scientific significance unless the structures of abilities that compose it are clear and defined. This structure manifests in achievement, and the next section will probe academic achievement - specifically achievement in Science programmes.

## 3.4 THE RELATION BETWEEN GENERAL MENTAL ABILITY AND ACADEMIC ACHIEVEMENT IN SCIENCE

In the previous section human mental abilities were discussed against the background of Carroll's CHC-model. Sternberg and Kaufman (1998:488) acknowledge the influence of Carroll's' framework as they "…masterfully integrate a large and diverse factor-analytic literature…" The educational and empirical evidence of mental ability is present in the achievement test results. Well designed scholastic achievement tests can serve the purpose of distinguishing mental abilities of learners and students in Higher Education. Achievement is measured against what has been learned (prior knowledge) and is rather reflective than predictive, with a retrospective purpose. Murphy and Davidshoffer (1998:33) explain that proficiency tests measure mastery of specific content (cf. Section 3.3.1.5). A well designed test will prove whether content is relevant or not, as it measures the process of thinking.

The following section (see Figure 3.6 for the outline) explores the literature on general mental ability manifesting in academic achievement. The focus remains the probing of predictors for future performance in Science (including Mathematics) in the South African context. The literature review explores the relevance and current state of Science and its link to general academic achievement, in order to do responsible placement of students in Science programmes at university.

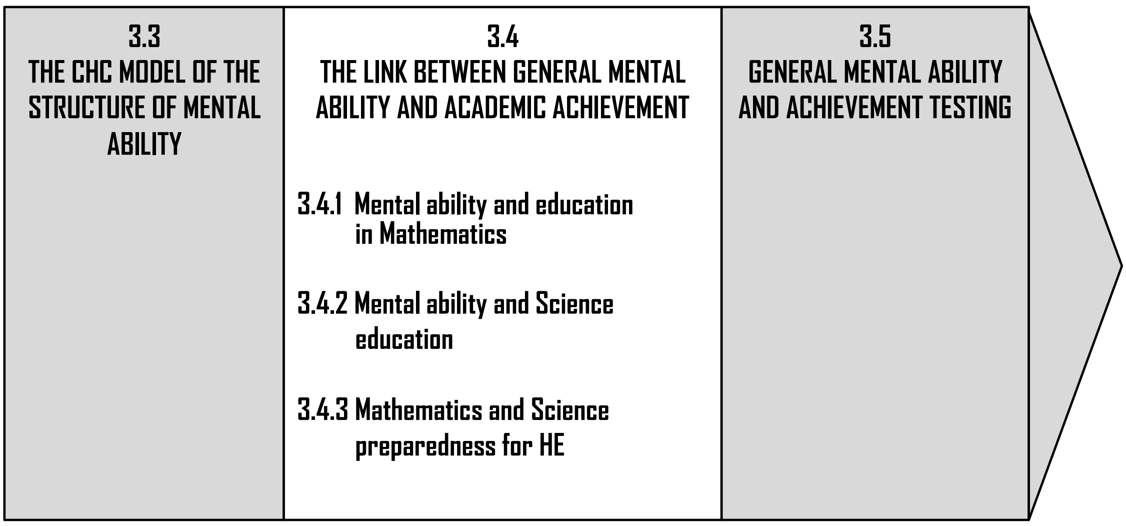


***Figure 3.6*** **The relation between general mental ability and academic achievement**

### 3.4.1 Mental ability and education in Mathematics

This literature review will explore the relevance and current state of Mathematics at school level, as well as investigate specific mental abilities related to Mathematics learning. The link of Mathematics to language and transfer of knowledge will be flagged. Finally, the study will relate Mathematics to general academic achievement, in order to recommend responsible placement of students in Science programmes at university.

#### *3.4.1.1 The importance of Mathematics achievement*

The Oxford Advanced Learner's Dictionary (2010:915) defines Mathematics as the "…Science of numbers and shapes, process using logical reasoning and symbolic notation." This study identified nine reasons pertaining to the relevance of Mathematics achievement for this study, not ignoring the fact that there will be many other aspects influencing Mathematics achievement. In the researcher's own experience (as both a teacher and a lecturer for more than 30 years), learners and students are generally unable to recall all the Mathematical content and procedures if they do not keep abreast of and repeat such processes frequently. The mind can exercise itself, and this will be valuable throughout life. This section will, however, not discuss non-cognitive and affective influences on Mathematics (such as self-esteem, self-efficacy and anxiety), as these will be addressed in the next chapter (cf. Section 4.7).

The following six motivations will state the case of Mathematics achievement being important for this investigation, as well as for the individual him/herself and the country:

a. Steen (2006:12) and Khan (2004:155) refer to Mathematics as an internationally recognised 'rite of passage'. Mathematics serves as the gateway to Science, Health Sciences, Engineering and Technology programmes. Students in Information Technology (IT) and Computer Science, as well as in Accountancy programmes, also require Mathematics as an admission requirement. Foxcroft and Stumpf (2005:3) identify mathematical ability as a core academic competency. Generic cognitive competencies – higher order thinking skills (cf. section 3.3.6) – and more so, critical thinking and problem-solving skills, are all evident in Mathematics. Maree (2009:267) concludes that Mathematics achievement impacts on the national economy of any country. Insufficient achievement will impact negatively on economic growth and sustainability, as a developing country relies on engineers, medical practitioners and scientists.

b. Mathematics forms part of almost every test battery for aptitude, proficiency or intelligence testing (cf. general mental ability, Section 3.2.6). Mathematics serves as an admission requirement for Higher Education programmes, due to its recognised predictive validity (Eiselen *et al*. 2007:39). In the USA, as reported by Huysamen (2002b:115) and Zwick

(2007:5), the Scholastic Aptitude Test (SAT) and American College Test (ACT) have been 'common yardsticks' to measure potential students' ability, with Mathematics having been a core component since 1926.

Under-preparedness in Mathematics is a worldwide concern (as stated by Huysamen 2002b:115) and Zwick (2007:5). In South Africa, the complexity of language proficiency adds to the challenge, as the majority of students learn Mathematics via the medium of English, and not in their mother tongue. Foxcroft and Stumpf (2005:7) refer to a study where the predictive validity of Grade 12 academic achievements in the second language was determined. As expected, students did not achieve as well as their peers who had the opportunity to be assessed in their first language. However, these authors condemn the compensatory mechanisms in South Africa to adjust second language speakers' marks (as is currently the practice).

c. Mathematics is an important component of the South African National Benchmark Test (NBT) compiled by HESA, which will be written nationally in future. The results will hopefully provide the HEIs with "…important information on the competencies of their existing (in the case of schools) and entering (in the case of universities) students…" (HESA 2006:1). The NBT assess entry-level academic and quantitative literacy, and Mathematical proficiency of students for admission, and possibly placement of students, based on accurate and fair selection. HESA (2006:5) also predicts that the NBT will provide Higher Education authorities with a "…grasp of the nature of preparedness…" of students, and enable Higher Education authorities to assess proficiency levels.

   HESA (2006:5-8) explains that the NBT will assess three areas or domains, namely: i) Academic Literacy (AL), ii) Quantitative Literacy (QL) and iii) Cognitive Academic Mathematical Proficiency. Quantitative Literacy is included, as it emphasises mathematical actions, such as making and drawing connections, visualising, questioning, representing, concluding and communicating. Cognitive Academic Mathematical Proficiency (CAMP) is based on the Grade 12 Mathematics exit level. It indicates Higher Education preparedness and provides a holistic profile of the prospective students.

d. The transfer of Mathematics into other disciplines highlights its importance. Tolstova (2006:21) is of the opinion that the "…way to provide substantial help in inculcating a taste of independent thinking in every school learner is to organise properly the teaching of Mathematics in the schools." For example, Mathematics is required for studies in Sociology. Lecturers and teachers of subjects such as Physics, Chemistry and Accounting make assumptions on acquired Mathematical knowledge and skills. In a study by Britton, New, Sharma and Yardley (2005:1-13), the transfer of Mathematics (specifically exponentials and logarithms) to other disciplines, such as Computer Science, Physics and Microbiology was tested. In many cases, the assumption was made that students could do Mathematics. "An education in Science starts with Mathematics…" (Britton *et al.* 2005:11), and although students perceive the Sciences as difficult, Marais and Marais (1999:82) found that problems usually result from in their inability to transfer Mathematics to Science disciplines. Maree (2009:270) adds that the transfer of technological skills also depends on Mathematical ability.

e. Mathematics enables learners and students to understand the world around them. Ancient cultures had to devise elementary counting symbols in a quest to communicate. Arithmetic, one of humankind's greatest intellectual achievements, was developed due to social pressure (this is still true today, as Mathematics is used to solve natural as well as social problems). Mathematics is used to help humans understand and adjust to their daily living (cf. Sternberg's successful intelligence referred to in Section 3.2.4).

"Mathematising" takes place when attempts are made to solve real-world problems by means of manipulating, retrieving memory, making decisions, reasoning, and drawing logical conclusions "…in abstract symbolic and complex context" (HESA 2006:36–37). The importance of Mathematics is emphasised by Tolstova (2006:22) by stating that it creates models that "…appropriately reflect real situations." The value of Mathematics in the world of art and culture, in creating acoustic images (shapes and compositions) is, according to Hendricks (1991:32), putting the finishing touches on the complete picture of the "beauty of Mathematics".

f. Mathematics has the ability to enable learners at school and students in Higher Education to perform creative (cf. revised Bloom's in section 3.3.6) and logical reasoning to solve problems. According to HESA (2006:35), Mathematics is practiced by all cultures and is "…constructed through the establishment of descriptive, numerical and symbolic relationships."

Mathematical literacy is a human right and allows one to function in the real world. It equips students with the ability to observe patterns which, in combination with rigorous logical thinking, can result in forming theories of abstract relations. Britton *et al*. (2005:11) explain that Mathematics is such a unique discipline that it not only results in past insights, but also develops new insights, a universal ability to communicate, and that is a valuable tool to adjust and manipulate the real world.

It is important to note, however, that there is now more Mathematics exposure at school level than before 2008 (cf. Table 2.5). Many more sound reasons can be added to previously provided motivations (cf. Section 2.6.2). The above motivations provide sufficient evidence that Mathematics achievement is important for Science, the country and the world.

Although the previous section focused on Mathematics, all the above reasons will be equally applicable to Physical Science at school level (cf. Section 3.4.2). No longer does the problem only pertain to teachers and learners or lecturers and students. With media accusations (cf. Section 2.6.2) the public domain took notice of the inability of public schooling in South Africa to provide prepared students for the Higher Education sector. The next section will elucidate the mental abilities required for Mathematics.

#### *3.4.1.2 Mental abilities required for Mathematics*

The mental abilities specifically needed to achieve optimally in Mathematics are varied. In the 16th century, Mathematics was written out in words, before notations were developed. At this time, only one symbol (e.g. Δ or Σ), contains a great deal of information (Lesh 2000). Mathematics thus requires precision of language and logic, also known as “rigour”. General mental ability describes mental aptitude rather than accumulated knowledge, and will correspond with the individual’s ability to “solve novel problems, think abstractly, and acquire and store knowledge”. The accumulation of knowledge represents adeptness in learning and understanding of new information.

Researchers Floyd, Evans and McGrew (2003:156) have been studying the links between measurements of broad abilities of the CHC-model (cf. Section 3.2.2), as well as narrow abilities applicable to Mathematics achievement and report as follows:

- Crystallised knowledge (Gc) (comprehension) and processing speed (Gs) have a strong link with the Mathematics cluster.
- Fluid reasoning (Gf) and long-term retrieval (Glr), as well as short-term memory (Gsm) are moderately related to visual-spatial thinking (Gv) and auditory processing (Ga), with little reference to the Mathematics cluster (Floyd *et al*. 2003:155).

An investigation into the maintenance of Mathematics skills by Floyd *et al*. (2003:155) identified seven factors that influence these abilities, including:

i) The importance of home-based educational resources.
ii) Development of a number sense and numerical deficits.
iii) Training of teachers in the school context.
iv) Time spent on Mathematics instruction will influence Mathematical achievement.
v) Inductive and deductive reasoning processes.

vi) Language processing.
vii) The addition of cognitive processing speed.

The environment at home, school, and specifically the classroom, contribute to the development of Mathematical processes and procedures (Eiselen 2006 and Maree 2009:272). In addition, consideration of the attributes of the discipline, student profile, competency and personality of the facilitator and the learning environment all form part of student success (Maree 2009:271). This study will therefore also focus briefly on other attributes of Mathematics that can enhance a model to place students in suitable programmes. The subsequent discussion emphasises an environment conducive to learning.

*3.4.1.3 The relationship between Mathematics and language*

This study does not review all the literature and research conducted on the influence of language on Mathematics achievement. It will focus briefly on word problems, since these become part of the methodology of Physics, Chemistry and other disciplines that apply Mathematics. The word problem represents a specific Mathematical language that is abstract, conceptually dense (compact) and complex. Bohlmann and Pretorius (2002:197) remark that the characteristics of Mathematical achievement are "…precision, conciseness and lack of ambiguity." Brune (2004:590) adds "correct" and "cogent" to the list of Mathematical attributes.

Mathematical language has its own vocabulary and syntax (Bohlmann & Pretorius 2002:197). As it consists of universal symbols it is internationally comparable. Translation is fundamental. Learners usually have difficulty in moving from numbers to the words of problem and searching for the rules of Algebra (Arithmetic at this level) to solve problems. This results from reading ability, even before Mathematical challenges. This encoding also creates problems for students at university level. The challenge to translate the word sentence into meaningful own words and then into a Mathematical equation is immense. Van Amerom (2003:63) adds that there is very little instruction and material to provide ways and means to solve the problem. The ability to perform the encoding, manipulate the words into an equation (modeling) and then compute seems to characterise higher order learning (analyses, synthesis, evaluation and creation).

Those who achieve in Mathematics are precise, can make decisions and argue convincingly with argumentation. According to Brune (2004:591), Mathematics is an elegant, concise language and easily understood. To inculcate Mathematical vocabulary and language in learners requires special attention (Van der Walt 2009:379). Learners must feel confident and proficient in the language before they can fully comprehend the Mathematical structure of a problem (cf. Section 3.4.1.1). Mathematics requires an integration of all relevant information.

Interaction with Mathematical texts should be attempted with attention and alertness (self-knowledge).

Learners and students in England, USA and China are able to read and answer Mathematical problems in their first language. In contrast, learners and students in Africa, as well as in other colonised countries, must translate reasoning to and from their mother tongue. In a study conducted by Adetula (1990:352) in Nigeria, he found that a lack of linguistic skills in second language students manifests in a lack of mastering the ability of Mathematics. Vygotsky (1962) revealed that if the language used to teach Mathematics is foreign, students will experience extreme difficulty to regulate own higher cognitive functions.

Maree (1994b:60-64) investigated the success of learning Mathematics in the home language. He found that learners who had been taught Mathematics in their home language achieved better than those taught in their second or third language. Both learners and students then find word problems extremely difficult.

*3.4.1.4 Mathematical achievement and the real world*

Mathematical learning begins with counting numbers in sequence (one, two and three). Already in Kindergarten, learners recite these in sequence, before any formal instruction takes place. Addition and subtraction (arithmetic computation) require practice to become automatic. In the next step, whole numbers are extended to fractions, decimals, logarithms and exponents to evolve into quantitative, creative and logical reasoning, modelling, symbolising and other abilities, all depending on meta-cognitive skills.

HESA (2006:35-39) stipulates that Mathematical modelling (formulating a problem) provides students with the ability to analyse and describe the real world, and to deepen mathematical understanding by comprehending text (cf. Section 3.4.1.5). Studying Mathematics requires a computational (rigid and mentally structured) procedure resembling a flowchart. There is a definite procedure and sequence (Wesi, Smit & Vreken 1999:175), but it seems as though learners and students are unable to translate information into a symbol-form.

Mathematical modelling (as described in Figure 3.7) is the key to understanding the real world. It is a balanced and integrative way of understanding Mathematics. Schools must prepare learners to solve problems. Wessels (2009:331-332) proposes that if learners can draw a diagram, indicate the sequence, develop significant mathematical constructs and then apply these in other problem situations, they will become acquainted with the pattern. In an investigation by Lesh (2000:74) on mathematical understanding and abilities, he identifies the fact that traditional schooling labels processing as operating, organising and manipulating information.

In Mathematical modelling, the focus is on connections and balance (Blum and Leiss in Wessels 2009:326). A connection must be found between the real world and the idea world (cf. Figure 3.9). This balance requires a nuance among concepts, relations, patterns, problem-solving and communication. Harding (2009:357) reports on an investigation of first-year students' Mathematics achievement in 2008. The students showed significantly poor ability in modelling and relations categories. They did qualify for entry into the module based on their Grade 12-results, but lacked the requirements for learning to take place. First-year students had difficulty with modelling and describing word problems in Mathematical terms, the core of first-year Mathematics.

A model emanating from this is the thought model of Farrell and Farmer in Hendriks (1991:34) that was adjusted to show the link between Mathematics and the real world. The modeling process starts with real world problems. In Figure 3.7, the movement between the 'real world' (physical world) and the 'idea world' (Mathematical world) is presented.

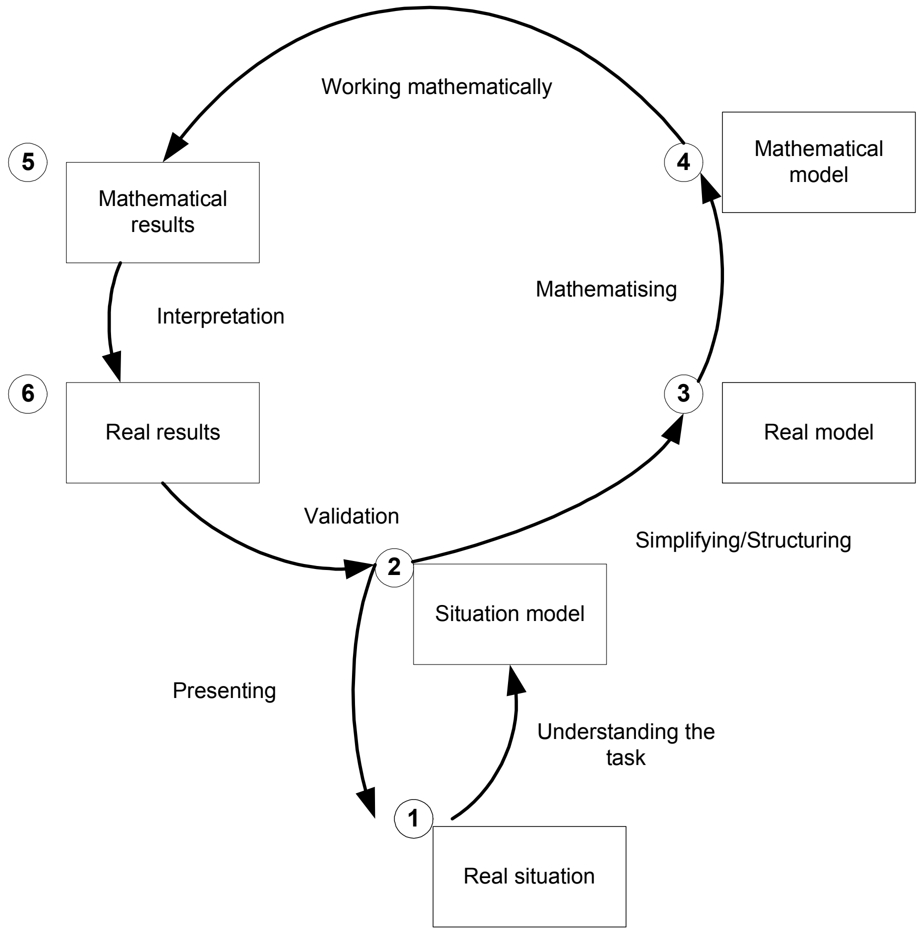


***Figure 3.7*** **The cycle of modelling in Mathematics**
(Adapted from Hendriks 1991:34 and Wessels 2009: 327)

A description of the process presented in Figure 3.7 follows (with numbers indicating the phases). The real problem must be understood [(1)]. The problem is then simplified and structured [(2)], thus mathematising [(3)] the real world to a mathematical model. A mathematical solution is then found [(4)], interpreted [(5)] and validated [(6)]. The situation model is then presented [(7)]. One must understand what is asked, then Mathematise (find the solution) and present the result.

According to Lesh (2000:74), most underlying mathematical constructs and abilities, require Mathematising. This includes dimensionalising, quantifying, coordinating and organising information in order to use tools and routines. These are not addressed in traditional schools (Lesh 2000:74). At university level, students are required to go beyond thinking about the tools they use, but unfortunately this does not happen.

Students with the abilities to simulate real life are often not those with high scores in achievement tests. The close connection among the above mathematical capabilities corresponds to the cognitive abilities (cf. CHC-model in Table 3.1). The role of the learning facilitator – the teacher at school or the lecturer at university – is changing. Teachers with no confidence, bad mathematical preparation and no passion will not be able to assist learners or students with moving from real world problems to modelling. On the other hand, the researcher is of the opinion that university lecturers are not prepared for students entering Higher Education. They find themselves in the 'idea world' and have lost touch with the inability of students, or they assume that students are already in the 'idea world'.

### 3.4.2 Mental ability and Science education

Performance in Science is often linked to mathematical ability. Physical Science at Grade 12-level has been proven an important predictor of success in university Science programmes (UJ 2008b:3). As with Mathematics, the university depends on content knowledge and skills that Physical Science provides upon having left school. In general, the first language, Mathematics and Physical Science serve as admission requirements for all programmes in Science, Engineering and Health Sciences (found on university web sites).

#### *3.4.2.1 The importance of Science achievement*

Science achievement is important for mainly eight reasons:

a. As is the case with Mathematics, the study of Science is a gateway to access Natural Science, Health and Biological Sciences, as well as Engineering and Technology programmes. The attraction of fields, such as Medicine, Engineering and Business Science can be found in their lucrative potential, resulting in a small remaining pool of students qualified to enter research careers in Science and Science Education, or to qualify as professional Scientists.

b. The transfer of mathematical content and skills are applied in Science, and thus mathematical competency will precipitate Science achievement. Both Mathematics and Science develop individual cognitive abilities (Naudé-de Jager 1994:102). In addition, Mathematics provides the language of expression for Science. Where Mathematics does not accept generalities, based on observation only, and will follow the cycle of deduction to prove validity, Science methodology will use induction to formulate general conclusions, based on specific findings.

c. Science is structured into many disciplines or areas of specialisation, such as Physical Science (Physics and Chemistry), Mathematical Science (Mathematics and Statistics), Earth Science (Geology and Geography) and Biological Science (Biochemistry, Zoology, Botany, Human Physiology and Anatomy). The modern approach includes Technology, which is applied in all the above mentioned disciplines. Science is also systematic study of nature (Maarschalk & McFarlane 1987:41). According to the Oxford Learner's Dictionary (2010:1320), Science is "Knowledge about the structure and behaviour of the natural and physical world, based on facts that you can prove."

d. Except for Mathematics, this study mainly focuses on Physical Science (Physics and Chemistry) as can be found in the school curriculum, because this is relevant for the prediction of successful studies in Science.

Physics is "the scientific study of matter and energy and the relationship between them" (The Oxford Learner's Dictionary 2010:1102). Physical principles constitute the basis of the physical world, according to Marion (1976:xii) and an important part of the knowledge one should possess, in order to understand and appreciate the world. It is a fundamental Science on which Biology, Geology and even Chemistry are based. The conceptual and theoretical framework created by Physics is applied in both the practical and technological world.

Chemistry on the other hand, is "the scientific study of the structure of substances, how they react when combined or in contact with each other" (The Oxford Learner's Dictionary 2010:241). As a fundamental Science, Chemistry provides the framework for the study of atoms, molecules and aggregates, which constitute biological and industrial processes in nature.

e. The importance of Science education and Science research in South Africa manifests in government decisions made in April 2009 (after the national election). The Cabinet appointed three ministers to be responsible for Science and Education; including a minister dedicated to Science and Technology, driving research and creating research opportunities. The creation of ten research chairs for Mathematics Education by the DoE, is proof of the ambition to increase high level research in Science education (RSA DoE:2009). Furthermore, South Africa also has two dedicated ministers for Education, namely one for Higher Education and Training and another for Basic Education (school education). The above appointments by the South African President strengthen the focus on and importance of Science in the highest corridors of power. Previously, one Minister of Education and another for Arts, Culture, Science and Technology managed all the aforementioned portfolios.

f. Philander (2009:172) discusses the need for Scientists in the country, in order to alleviate poverty and illiteracy. He argues that scientific research should no longer be measured by citations in publications, but rather by graduate success in Science. The researcher is of the opinion that the current emphasis on research outputs and the promotion criteria, based on these outputs shifts the attention of university lecturers to primarily perform research. Lecturers should also conduct research into the teaching and learning they are involved in, mentor students and create a pool of postgraduate students while they are "learning to become a scientist" (Pretorius & Jacobs 2008). Science teachers at school level also have the opportunity to nurture and cultivate a scientific orientation from a very early age. The planting of these special seeds will ensure a harvest of Mathematicians, Scientists and Science teachers in future, only if university lectures continue with the same care and nurturing.

g. In a study by Lynch, Kuipers, Pyke and Swesze (2005:914) on teacher training, it was found that teachers who entered professional development programmes were outperforming peers (without appropriate training) by 44%. Naidoo and Lewin (1998:740) indicate that less than 20% of Science teachers were trained at university. Many trained Science teachers are also currently teaching Mathematics, or are involved in governance responsibilities. The challenge in South Africa will therefore be to equip current Science teachers and to recruit successful Science graduandi to become Science teachers.

h. The formative value of Science in the revelation of nature, and the subsequent impact of Science literacy on an individual or a community, are important factors to consider (Maarschalk & McFarlane 1987:70–73). Similar to Mathematics, Science enables learners and students to understand the world around them (by means of problem-solving, interpreting, application and innovation). The declining number of students in Science (and even less achieving in Science) is of international concern.

The above indicate why Science achievement is important for the purpose of this research. Mental processing of Science will be addressed subsequently.

*3.4.2.2 Mental processing in Science*

This type of processing relies on observation and direct experience, accumulation of information and structuring and interpreting such information (Naudé-de Jager 1994:97). Intellectual skills, as identified by Gagne (1985:47), include the ability to perceive the environment in terms of symbols (similar to modelling in Mathematics, Figure 3.7 p.101). Learners and students should also acquire the skills of discrimination, classification and emulation of rules (Naudé-de Jager 1994:159; Maarschalk & McFarlane 1987:40-81). In addition to the aforementioned, Science contributes to the acquisition of motor skills, such as sensory activities, operating instruments, accurate measuring and observation.

Linn (1990:297–318) identifies problems with which students in Science are confronted, the main categories of deficits in Science performance being the fact that students have a limited processing capacity and that the reasoning ability to solve problems must include strategic planning to think about own reasoning (higher order learning). As discussed in the previous section on Mathematics, students must consider and combine known content and approaches to solve new problems. The solution must then be tested to establish whether it is indeed the solution or whether another option should be generated.

Science knowledge and concepts rely on intuitive conceptions and methodology. It influences the way the learner/student attempts to solve the given problem, either by "…loosely structured associations to search their knowledge base …" or by testing ideas with "…if and then…" in analysing the consequences of every decision (Linn 1990:297–318).

Science cognition can be divided into skills and strategies (Naudé-de Jager 1994:174-179). The skills required in Science are basic and simple - for instance, speed, accuracy, recall and analysis. Motor and sensory skills are applicable in the laboratory and are extremely important, in order to apply content knowledge. Strategies such as decision-making and problem-solving, are however, more complex in nature. To be successful in Science, a student is required to be able to abstract, relate, learn, solve problems (with symbols and words), act purposefully and be able to adjust to the environment (general mental cognitive abilities). Students need cognitive strategies such as decision-making, conceptualising, critical thinking, acquiring knowledge, comprehending, applying, analysing, synthesising and creating (cf. Bloom in section 3.3.6 and Modelling in section 3.4.1.2).

Achievement in Science requires students to identify patterns, perform practical experimentation, make decisions, do critical thinking and perform information processing. In a study conducted by Cilliers and Sternberg (2001:20-23), the Science students significantly favoured an executive thinking style resembling the following of directions, implementing and completing tasks requiring much structure. A comparison of Science students in different programmes by Cilliers and Sternberg (2001:22) indicates that they prefer to deal with large and global issues, generalities and abstractions. Science students also adhere more to rules and conventional ways, compared to Education and Arts students.

Scientists are required to think about and answer conceptual questions. According to Philander (2009:172), the scientific approach of experimentation requires real scientists in action (university professors). Being surrounded by knowledge experts and having facilities (library, laboratories and equipment) to support this inquiry into Science will enhance a scientific approach. This also refers to the "learning to be" concept discussed by Pretorius and Jacobs (2008).

Mental processing in Science is similar to mathematical modelling where the 'real world' is connected to the 'idea world' in order to achieve problem-solving (Maarschalk & McFarlane 1987:41). In the scientific model the proving and producing facts by experimentation is induced, and thus the inference from particular data to a general law formulated as a theory. The theory is developed, and the deduction phase commences. The inference from the general law (real world) to find a particular solution (idea world) results from cognitive processes, such as finding, reasoning, abstraction and critical thinking.

This investigation does not indulge in a psychological scientific declaration of mental processing. With reference to Bloom's taxonomy (cf. Section 3.3.6) and CHC-model (cf. Section 3.3), a student with the general mental ability to analyse, evaluate and create should be able to achieve success in both Mathematics and Science. Solving mathematical and Science problems requires high-level competencies that have already been discussed (cf. Section Table 3.1).

In Section 2.6.1.2, the achievement of Grade 12-learners in Physical Science was reviewed. The next section will probe the state of Science education in South Africa.

#### *3.4.2.3 The current state of Science education in SA*

The need to provide students with new scientific and technological literacy at school began in the USA in 1983 (Linn 1990:297–318). Mathematics and Science require problem-solving skills, in order for learners to understand and use the current technological world they live in and more so, for the future (Human 2009:305). The rapidly changing world can be measured against the fact that it took 32 years to accumulate the first million entries in the Chemical Abstracts (Linn 1990:297–318). It took only two years to accumulate the second million entries. Knowledge available to acquire is growing exponentially, while the ability of learners at school and students at university is not developing to the same extent.

The purpose of Science Education should be to provide enthusiastic and questioning students who will themselves become scientists (Naudé-de Jager 1994:97). The purpose should also be to create a scientifically literate community. This will result in rational thought and action, and will ultimately create an awareness of preserving and being positive about the environment. Five challenges of South African Science education are discussed below.

a. The lack of qualified Science teachers creates a problem. The phenomenon of teachers teaching "out of their field" or with little education or training is a difficult challenge to manage. In American schools the problem of 'out-of-field' teaching has become a prominent theme. Ingersoll (1999:26) reports that more than a third of "…all secondary school teachers of Science have neither a major nor a minor in Mathematics or Science." A lack of qualified teachers, teacher and learning quality and teacher commitment are special concerns in Science education. According to Ingersoll (1999:26), less than one fifth of all American Science teachers are equipped to teach Science.

   Naidoo and Lewin (1998:73) conducted a survey and found that in South Africa, only 66% of current Science teachers were qualified to teach Science (less than 10 000). Of the 66%, only 4% were teaching Physical Science (approximately 600) while the remaining 62% were teaching other subjects, leaving Science teaching to novices. If the country's 27 000 schools could employ all 600 Science teachers every school would have only 0.02 qualified Science teachers.

   If the purpose is to provide enthusiastic and questioning scientists, it is questionable whether an under-prepared or 'out-of-field' teacher will achieve. The South African curriculum requires all school learners to take Mathematics and Natural Science as compulsory subjects for at least nine years of schooling. Only after successful completion of Grade nine learners are allowed to select their Further Education and Training (FET) subjects. Then they have a choice between Mathematics and Mathematical Literacy, and inter alia, Physical Science from Grade 10 to 12.

b. The facilities and infrastructural requirements to provide quality Science education is a major challenge. Currently, the Physical Science curriculum requires learners to develop a sound knowledge base, apply their knowledge in practical experimentation and acquire practical skills (Maree 2009:262). In an investigation conducted in one of the nine provinces in South Africa, it was revealed that only 50% of schools in this region had Science laboratories (Masehela 2005:21). Only 68% of the schools with laboratories had electricity, while only 48% had gas and water available. In 35% of these school teachers declared that they had used the laboratory for practicals only once while others used the facilities once or twice a month.

c. The small pool of potential Science students, especially Black students, also presents a challenge. Masehela (2005:21) reports that only one out of every five Black learners in South Africa selects Physical Science at the end of Grade 9. According to Masehela, this results from a lack of teachers, no career-counselling and poor resources and interest in Science fields. The achievement of Black students in Physical Science is a major concern. Hattingh (2009:342) indicates that only 2.6% of the 14 000 Engineers in South Africa are Black, only 7.5% of 33 000 medical doctors in South Africa are Black, and 1.6% of 4 000 South African dentists are Black. This is a concern as Blacks represent 79% of the South African population. The number of successful Physical Science students declined from 110 000 (in 2004) to 23 000 (in 2008), of which only 13% are Black.

d. A major challenge for Science education manifests in the difference in cultural background of students. Matoti and Lekhu (2008:126) present a recent study conducted with students training to become Mathematics and Physical Science teachers. They investigated problems encountered by first-year teaching students. The results indicated that the adjustment and transition from school to Higher Education created a problem of new cognitive and metacognitive demands that had to be met (Matoti & Lekhu 2008:28). Students encountered problems with their own expectations and newly acquired independence. They move from one culture to another - specifically in Mathematics or Science, a phenomenon labelled as cultural 'border-crossing'.

The conflict between indigenous knowledge and the world of Science can be best explained by the metaphor of the formation of the rainbow. The researcher uses this metaphor as a means to explain the problems first-year students are confronted with. In Physics, the formation of a rainbow is explained as being a result of the rays of the sun refracting through the water drops. The indigenous belief of a rainbow appearing when a "python crosses a river" or signifying the "death of an important chief" can confuse students in a Science lecture (Matoti & Lekhu 2008:127). Learners from Christian backgrounds also often find it traumatic to deal with evolution and educators must be sensitive and knowledgeable when conveying such scientific theories.

Animism, explained as naive Science (ingenuous), is important in the South Africa context, where lightning is explained as personifying a god (also referring to Thor in Greek mythology) or a python laying eggs. This knowledge belief is transferred over generations. The concept of electricity and conduction being the reason for lightning seems far-fetched to a Black student from a rural village. Matoti and Lekhu (2008:29) explain that the proof of scientific facts causes animism to diminish, but students retain a respect and value for these aspects in nature.

e. The final challenge that Science education specialists are concerned about is the language barrier, as the language of teaching and learning influences Science performance. In the South African context, multi-lingualism complicates this matter. Science language differs from everyday spoken language. The interchangeable use of terms, such as speed and velocity, distance and displacement, power and energy, creates misconceptions that are difficult to correct at a later stage, for example:

- In Xhosa "Amandla" is the exact same term used for energy, power and masculinity – each with definite meaning and implication variations (Matoti & Lekhu 2008:128). Energy (measured in Joule) and power (measured in Watt) are related concepts, but not the same when derived for the Xhosa learner.
- According to Matoti and Lekhu (2008:128), "Ukunyibilika" means melting (solid phase to liquid), but also dissolving (solute dissolving in solvent). Again, these are two different processes and can most certainly not be described by the same word.

The switching of codes from mother tongue to scientific discourse is highly problematic, especially if lecturers are ignorant of the misconception. In a recent training session, a Grade 12-teacher asked: "What is torque?"– pronounced with a Xhosa click of the tongue. The teacher clearly had never heard about this term used in mechanics and would hardly be able to explain it to learners (Kriek 2008).

*3.4.2.4 Science achievement at Higher Education level*

There is an international drive to recruit students to study Sciences, with Blankley and Arnold (2001:65) expressing concern that students have a preference to study Commerce and earn good salaries. In South Africa, a similar trend can be observed. Table 3.3 indicates the enrolments in SET, from 2004 to 2007. The 2008 and 2009 data is not available yet.

**Table 3.2** ***The Enrolments and Graduations in Public Higher Education Institutions in SA in Science, Engineering and Technology***
(Adapted from CHE 2009:37)

| **Field of study (CESM)** | **Science, Engineering and Technology** | | | |
|---|---|---|---|---|
| | **2004** | **2005** | **2006** | **2007** |
| **Total enrolments in HE** | 744 489 | 735 073 | 741 380 | 761 090 |
| **Total graduations in HE (in minimum time required)** | 116 561 (15.6%) | 120 418 (16.4%) | 124 615 (16.8%) | 126 640 (16.6%) |
| **Enrolments in SET** | 202 552 (27.2%) | 210 707 (28.7%) | 211 585 (28.6%) | 209 985 (27.6%) |
| **Graduations in SET (in minimum time required)** | 30 383 (26.1%) | 33 506 (27.8%) | 34 478 (27.7%) | 35 257 (27.8%) |

Table 3.2 indicates a slight increase in total enrolment figures, as well as graduation figures, from 2004 to 2007. However, the percentage participation of SET in total enrolments remains approximately 28%, with a similar graduation rate. A positive finding that can be deduced from this table is that the percentage graduations in SET (average of 27.5%) compares favourably with total graduations (average 16.5%).

Given the transformation agenda, the distribution of ethnic groups was investigated by SAIRR (2008b:1). According to this research, White graduates will continue to dominate the professional sector in the country, at least for 2010. This will create an even larger imbalance for the Black Economic Empowerment (BEE) sector and affirmative action provisions (cf. section 2.2). The field of Science has even less students from which to select, let alone achieve transformation targets. The shortage of students refers directly to the shortage of qualified and dedicated Mathematics and Physical Science teachers. In 2008, Minister Pandor remarked that good teachers create a pool of potential scientists for South Africa. As stated above, there is a concern in terms of representation and participation in SET, but also the quality of students entering universities.

In research conducted at a South African university (Saayman 1997:155), the comparison of student results after a few months at first-year level indicated a remarkable deflation of school achievement. This probe indicates that Science and Engineering student performance had almost declined by 25% from school. Students in their first year of medical studies (selected students) showed a 33% performance decline from school to first year. The students failed mainly the Physics module and, although top achievers, they were unsuccessful. In other investigations, Naudé-de-Jager (1994:174-179) and Faculty of Science (UJ 2008b) indicate that Physics had the lowest prediction for first-year achievement of the three gateway modules (Mathematics, Chemistry and Physics).

The ‘gap’ between school and university refers to the “…discontinuity between attitudes to learning, amount of work, intellectual environment…” (Grayson 1996:993). In the late 1960s, Gerrans (1986:541) identified students inadequately prepared to cope with Higher Education demands. The University of the Witwatersrand (WITS) introduced the so-called Star Schools and a Pre-University School as far back as 1975. Students could attend a four-week course and adjust to the new environment while enrolling for one of five modules (Mathematics and Applied Mathematics, Physics, Chemistry, Biology). In addition, all attended a course in Study Skills. Grayson (1996:1004) subsequently identified that the universities would be obliged to develop conceptual understanding and problem-solving skills of new Physics students.

In 2008, an analysis of Grade 12-results and university achievement was conducted at the University of Johannesburg (2008b), showing a significant discrepancy between school and university achievement. In 2009, the first group with the National Senior Certificate (NSC) entered Higher Education with high expectations. At one university, only 17% of first year students passed the first Chemistry test in 2009 (Beeld 09 April 2009c:1), in comparison to 47% who passed a similar test in 2008. The Mail and Guardian (22-30 December 2008b:25) mentions that many students who would probably not have qualified and have been admitted in previous years, entered universities in 2009. Another institution declared that in the mid-year examinations, only 35% of Engineering students passed in 2009, compared to 71% in previous years (The Times Higher Education supplement 25 July:1).

South African Universities were seemingly not prepared to deal with students from the Outcomes-based Education system and a National Senior Certificate. Many more students enrolled at institutions in 2009 (cf. Table 2.8), the larger classes creating logistical problems and high failure rates (Volksblad 04 August 2008:4).

### 3.4.3 Mathematics and Science preparedness for Higher Education

The preceding discussions scanned Mathematics and Science Education in South Africa. The importance of both Mathematics and Science was highlighted. Grade 12-results and the challenges for Science Education concluded the probe into Mathematics and Science preparation that should take place in the school environment.

A lack of research into Mathematics teacher education was mentioned in the early nineties by Paras (2001:66–73). Yet, nothing changed over the past 15 years. The study of Paras, performed on candidate Mathematics teachers at first-year level, indicated a gap between these students' preparedness and a lack of programme content, tempo and lecturers to bridge the gap. Therefore, whereas 91% passed the relevant module in 1990, the pass rate decreased to 55% in 1993. From 1995, less than 40% have passed, and admission requirements were relaxed, as from 1995. The above research highlights the need for an instrument to advise on admission and enrolment in Sciences, and is also reiterated by Yeld (2005:50), Nair (2002:94-103) and Blankley and Arnold (2001:65). South Africa requires 21 000 new teachers per year (Rademeyer 2009:395), but is currently only producing 5 000 teachers annually (Zille in the Mail and Guardian 24 July:3). South Korea (with a comparable population to SA) produces 30 000 Engineers per year, with SA only producing 1 400 qualified Engineers per year.

The above discussions focused on the importance of Mathematics and Science for a country's future success. General mental ability and an aptitude for Mathematics or Science contribute to success in these disciplines. However, South African universities rely mainly on the Grade 12-results as admission requirements. Maree (2009:275) expresses concern that admission rewards school achievement and is not used to identify unrealised potential. Foxcroft (2009) reiterates that admission should not rely on only one criterion (such as school results). In Science (including Mathematics), the focus is on prior learning. The 12 years of schooling in foundational knowledge impacts on the subsequent achievement at university level. The holistic preparedness (socio-economic, school and family, as well as personal and mental) contributes equally to student success (Maree 2009: 270).

The 2009 student cohort entered their first year in Higher Education with good school results. These good results were supposed to be the result of learners working efficiently at school and quality teaching taking place. In contrast, concerns were expressed by Engelbrecht *et al.* (2009:290) and Beeld (09 April 2009:1) that final examination papers mirrored trial examination papers (provided to learners beforehand). Their Grade 12-results resulted in the majority of first-year students entering main stream modules (extended modules were not an option, as these students met the admission requirements for main stream modules). The following question is therefore asked by the researcher: "Did institutions place the students in the most appropriate programmes and/or modules or did the Grade 12-results influence the decision?" The informal investigation launched by the researcher indicated the latter – students qualified, spaces were available and they were enrolled (regardless of risk factors).

This study proposes that when students apply, a procedure should be put in place to ensure that they are 'placed' in a programme, based on their student profile (cf. Section 7.3.3.2). Placement must be preceded by an analysis of the academic programme profile, e.g. what does the programme require? What is the profile of successful students in the programme – how well do they "fit"?

### *3.4.3.1 Access into Higher Education Science programmes*

The admission of students into university has been directed by admission requirements, as determined by Higher Education institutions in South Africa. The Senate of every university ratifies proposals made by faculties/schools, and admission requirements are determined (UJ 2009a). Prospective students are recruited in different ways and means and then apply to the institution of their choice. In many cases, students apply to more than one institution or for more than one programme. Institutional administrators will check if students adhere to the requirements and will then present the application to the Head of the Academic Department, who will make the final decision.

The number of applicants at the University of Johannesburg increased during the past four years (UJ 2008a). The 'capping' of numbers now challenges institutions to make in-depth choices about which and how many students they should admit. Most applicants apply with Grade 11 school results – which might differ from the final Grade 12-results in many cases (Nel & Kistner 2009:963). Institutions then notify students whether they had been admitted, and upon receipt of their final results students will arrive to register.

Institutions register students who, firstly, qualify, secondly, have secured placement (applied before the due date) and finally, have all the required documentation, stating that they can be admitted. Institutions assume that students have made the correct programme selection and know what they wish to study. In the experience of the researcher, little counselling takes place at school, and only very dedicated students have any idea of what they wish to study. The students from affluent schools and homes will have experience of career counseling, but the majority will not been exposed to this service. Even good students experience difficulty with the transition and might change courses/modules after a while. Many students drop out (cf. Table 2.3) who could have been assisted if placed in an appropriate programme.

Student drop-out increases, as many students register without prior application (Beeld 4 May 2009e:13 and UJ 2009d) over the past two years. A major concern for institutions has been the so-called 'walk-in' students (Beeld 05 May 2009:13). They only apply to institutions in January, after the Grade 12-results have been released. In many cases, they did not qualify in the previous year, but their final results are sufficient. In other cases, they do not have the financial means to apply at an earlier stage. At the beginning of the year these students queue at enrolment offices with the majority missing out on orientation and the first weeks of lecturing. Students who know what and where they want to study are usually motivated to work hard and be successful. Those who are uncertain, usually struggle and lack drive, thereby contributing to at-risk profiling, with alternative access routes being proposed.

Upon completion of Grade 12, students subject results are accumulated to calculate a total M-score (matric score) applicable to the Senior Certificate (up to 2008) or an Admission Points Score (APS), applicable to the National Senior Certificate (Wits 2009, UFS 2009, UP 2009, UJ 2009, UCT 2009 and SU 2009). In Table 3.4 the numeric value equalising the results (% or symbols) achieved, is presented.

***Table 3.3 Conversion of Final School Results to M-score and APS***
*(Adapted from Rademeyer & Schepers 1998:34; Eiselen 2006: 36; Websites of Wits; UCT; UFS, UJ, UP and SU 2009)*

| *% achieved* | *Symbol obtained* | *Until 2008* | | *From 2009* |
|---|---|---|---|---|
| | | *M-score* | | *APS-score (NSC-scale of achievement)* |
| | | *HG* | *SG* | |
| *80 – 100* | *A* | *5* | *4* | *7* |
| *70 – 79* | *B* | *4* | *3* | *6* |
| *60 – 69* | *C* | *3* | *2* | *5* |
| *50 – 59* | *D* | *2* | *1* | *4* |
| *40 – 49* | *E* | *1* | *0* | *3* |
| *33 – 39* | *F* | *0.5* | *0* | *2* |
| *25 – 33* | *G* | *0* | *0* | *1* |

In most local university programmes, the following minimum final results are required for admission into Science programmes:

- English, Mathematics and Physical Science results range from a value of 4 to 6.
- The APS (total accumulative score) ranges from 20 to 45.

Admission into Engineering programmes at the abovementioned Higher Education institutions requires the following:

- Mathematics and Physical Science results mostly a value of 6.
- The APS is in the range of 30 to 45.

It should be noted that the maximum value for the calculation of the M-score was 5 (for a achievement of ≥ 80%). This value increased to 7 with the APS-rating (in 2009). The M-score can be calculated as: 6 subjects x 5 (A-symbols) = 30 (maximum). The APS with six subjects (excluding Life Orientation) can be calculated as: 6 subjects x 7 (above 80%) equals 42 (maximum).

*3.4.3.2 Alternative access into Higher Education Science programmes*

All South African Higher Education institutions have already recognised problems in Science Education and have developed strategies to combat the high failure rate and low participation rate in Science programmes (and other fields). In most alternative access programmes student selection is a major directive. The agenda of redress and transformation was the drive behind some programmes, but currently access for success is a high priority. Identifying the student with potential to be successful is important. Another debate (which however, does not form part of this study) is the proposal to first improve the quality of teaching and then widen access, and not to perform both processes simultaneously (Naidoo & Lewin 1998:737).

The Government supports Higher Education institutions with earmarked funding for foundation programmes and, currently also extended programmes. These programmes attempt to widen access and provide admission to students who do not qualify and/or adhere to admission requirements. These programmes can also serve as an articulation route for unsuccessful main stream students to successful graduation. The models of alternative access and academic support differ in Higher Education institutions in South Africa. The extension of the first year to two years, additional academic support, and foundational provision in academic literacy and language, are all embedded in the various models. The future challenge will be to determine when and where to begin lecturing fundamental content and skills in the specific disciplines. Counselling and career guidance should also form part of access for success, in order to prepare students to make suitable and responsible decisions (Pretorius & Bohlmann 2003:231).

This research focuses on Science programmes and probed programmes to widen access in Higher Education in SA. As mentioned above (cf. Section 3.4.2.4), WITS University already began with "Pre-University School" for the first four weeks of an academic year in 1975 (Gerrans 1986:541). At the University of Natal (UN), a bridging programme was initiated (from 1998) to enhance the Mathematics and Physical Science levels of students entering Higher Education. The Students and Youth into Science, Technology, Engineering, and Mathematics (SYSTEM) programme at UN provides students with the opportunity to enrol for Science studies after a year (Van der Flier, Thijs & Zaaiman 2003:400; Grayson 1996:993-1013). In this enhancement programme, students build a foundation for meaningful learning during a phased transition.

At the merged University of KwaZulu-Natal (UKZN) there are currently two programmes, namely the Foundation and the Augment programme. The Foundation programme prepares students for Mathematics, Chemistry, Biology and Physics, as well as provides language support. The Times Higher Education Supplement (25 July 2009:3) reported that the UKZN students also do life skills programmes and have access to counselling. In the Augment programme the students select only two subjects and focus only on these for the first year.

In 1993, the University of the North (UNIN), now the University of Limpopo, introduced the UNIN Foundation Year (UNIFY). This is aimed at preparing disadvantaged students for admission into Science and also to improve their chances of completing a BSc degree successfully (Van der Flier *et al*. 2003:400). The University of the Witwatersrand (WITS) developed the Science Foundation Programme within the College of Science, where students complete a first year of Science over two years (Mumba, Rollnick & White 2002:150), but this programme has since been terminated. The University of Pretoria (UP) initiated the University of Pretoria Foundation Year (UPFY), while at RAU (now UJ) the SET Foundation programme was introduced, to mention but a few (UJ 2008a:4).

The University of Johannesburg (UJ) is currently enrolling students in extended programmes in Science, as well as Engineering (degrees and diplomas). In these programmes the students at UJ complete the first year with equal credits and content, as covered during the main stream first semester, and in the second year they do the main stream second semester (of first year). This extended model has been fairly successful, and in many cases, students from the main stream articulated into the extended programmes after the first assessment or the first semester (UJ 2008a).

At the University of the Free State (UFS) the “University Prep” programme (previously Career prep) follows a unique curriculum to provide alternative access. Students who do not adhere to the UFS admission criteria can register for one of three programmes. The programme in Natural and Agricultural Sciences is relevant to this study, with students accumulating credits towards a qualification. The “University Prep” programme includes a choice of different delivery sites (four in the Free State, Oudtshoorn and Kimberley) or any of two campuses in Bloemfontein and Qwaqwa making access available for all students (UFS 2009). The UFS is collaborating with FET colleges to offer similar modules. The programme began in 1993, with 73 students. By 2009, 962 students had enrolled. The Mail and Guardian (16 April 2010:2) reports that of the 1 111 students having graduated after having entered via this programme, seven have since become medical doctors, while 16 have obtained masters’ and 113 honours degrees. Another 180 of the students who moved to the Central University of Technology (CUT) have graduated since.

The students in the “University Prep” Science programme begin with Chemistry and Mathematics at first-year university level, a course in Skills and Competencies for Lifelong Learning, an English language course and a Basic Computer Literacy course. In addition, they complete N4 Further Education and Training Modules in Computer Practice and Communication. This results in students earning credits in diverse specialisation areas, opening up many opportunities for further studies.

This study aims to consider placement and access, including alternative access in order to establish a framework for placement. The role of achievement testing when providing access to students will be discussed subsequently.

## 3.5 GENERAL MENTAL ABILITY AND ACHIEVEMENT TESTING

Given the above discussions on the structure of mental ability, as well as its application in Science and Mathematical fields, the focus of this chapter will shift to the measurement of the student ability and potential, nationally as well as internationally. A brief review on the decision-making process and information acquired from testing batteries will follow. Finally, this section will explore current admission and placement practices in South Africa.

Figure 3.8 below provides an outline of section 3.5 of this chapter.

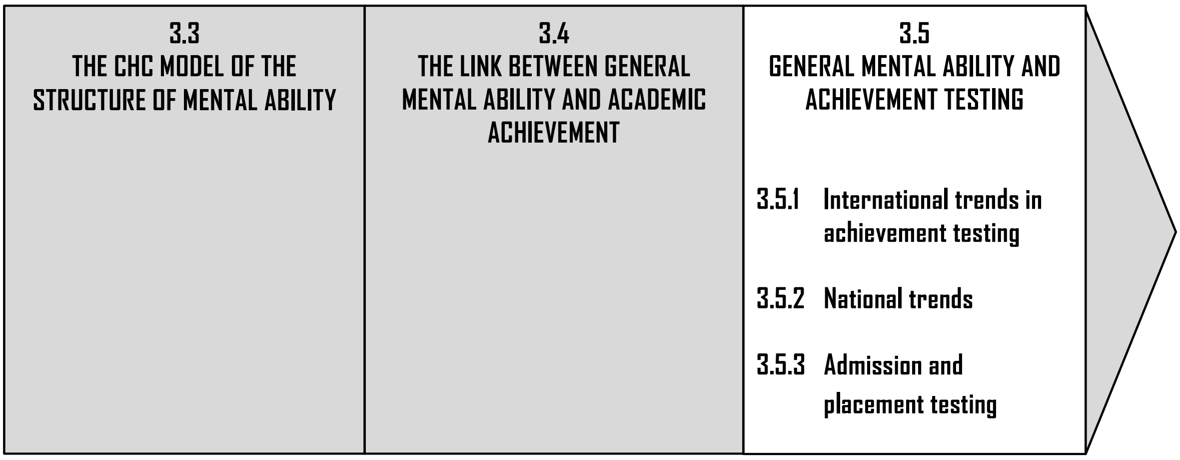


***Figure 3.8*** **General ability and academic achievement**

The literature review in this chapter indicated that general mental ability testing remains a good predictor of academic achievement. Academic achievement refers to successful completion of a module or programme. Some successful students could have entered Higher Education adequately prepared while others might have only acquired some skills and competencies by means of interventions or instruction during university exposure. How does one know what type of intervention or support students require?

Eiselen *et al*. (2007:38) and Foxcroft and Stumpf (2005:10) indicate that previous academic achievement is a good indicator of future academic success. The second-year student presumably passed most of the first-year modules successfully. The previous academic achievement in this context will therefore be represented by previous results. Engelbrecht *et al.* (2009:291), Nel (2009) and Foxcroft (2009) express concern when the track record of previous academic achievement is based on unreliable sources (cf. Sections 2.6.2 and 3.4.3). In addition, school achievement cannot predict future achievement (whether good students fail, or change study fields or their performance do not correlate with previous records).

This study mainly focuses on predictions of South African students' success in Science programmes upon entering university. An attempt will be made to propose a framework for the placement of potential students in suitable academic programmes at appropriate levels. A study of international trends will provide valuable insight.

### 3.5.1 International trends in achievement testing

Colleges and universities all over the world have been developing and utilising aptitude tests for more than a century as cost-effective and efficient ways to select students (Murphy & Davidshofer 1998:394). These two researchers claim that "…these programs rely on the premise that scholastic aptitude tests can effectively measure those abilities that are required to learn those types of materials usually encountered in academic courses."

#### *3.5.1.1 The American testing system*

The USA has used the American College Test (ACT) since 1959, the Scholastic Assessment Tests (SAT) since 1926, and the Graduate Record Examination (GRE) during the past two decades (Huysamen 2002a:140). The results of these tests, combined with past academic achievement, equate statistically to provide a predictive value for potential academic success and indicate any additional support required by students to be a useful diagnostic tool. In a publication by Murphy and Davidshofer (1998:515–516) a list of forty representative tests are recorded and placed in categories of intelligence and scholastic aptitude, multiple aptitude, neuropsychological ability, personality, sensory-motor and vocational tests.

The American education system (school and Higher Education) relies on a grade point average (GPA), but this remains equivocal when comparing any cluster of subjects to each other (Huysamen 2002a:140). Purely comparing results without distinguishing between the various disciplines that have been tested, would, however, be unscientific. Students would, for instance, perform better in History than in Physical Science, which would decrease the average of students with the latter major (also true for the calculation of the APS). Ramist, Lewis and McCamley-Jenkins (in Huysamen 2002a:140) identified three factors contributing to the GPA of first year studies, namely:

i) High aptitude for work at Higher Education level.
ii) Good achievement at school.
*iii)* The selection of university courses.

*3.5.1.2 Other international testing systems*

China's Emperors have been assessing the competency of public servants since 2200 B.C. and, later, in the time of Charlemagne, this was expanded to the army. This testing system was brought into disrepute by the Cultural Revolution (Sattler 2001:1). In 1966, the Chinese started testing for selection into the Communist Party once again, but soon fell behind, especially in Science and Technology. Since 1977 China has restored the practice of entrance examinations for further studies (Huysamen 1997:66). In Sweden, the need to compare common preparedness resulted in the development of the Swedish Scholastic Test (SweSAT). In Israel, the Bagrut certificate provided admission to universities from 1960 to 1969. Japan has a well established university entrance examination admission, allowing entrance into the country's 1 200 four-year universities, two-year colleges and technical colleges (Times Higher Education Supplement 02 February 2007:4).

Other tests applied in the world are: The Queensland Core Skills test (Australia); English as a Foreign Language (TOEFL) used in the UK; The International English Language Testing Service (IELTS), developed by the University of Cambridge Local Examination Syndicate; and the English in Educational Purposes (TEEP) in the UK (HESA 2006:17).

*3.5.1.3 Criticism of international testing systems*

Criticism of the abovementioned tests by Murphy and Davidshofer (1998:394), include the following:

- Possible bias in favour of White, middle-class students.
- The inability to predict academic achievement after school.
- Coaching that can inflate results and gender bias.
- Failure to measure the subtler traits of character (Huysamen 1997:67).

The advantage of testing other than for admission into Higher Education is the identification of problem areas as a diagnostic instrument to plan educational interventions and strategies (Huysamen 1997:67). In addition, Murphy and Davidshofer (1998:394) comment that test results may be applied for career planning, such as in the military and in other industries.

The international trend of admission based on a combination of information (admission test achievement and prior achievement, e.g. at school level) is becoming standard practice, with mixed results on the predictive validity. Astin (2004) studied predictors of degree completion and identified the following two predictors as important:

i) Academic preparation (if school grades correlate well with SAT-achievement).

ii) Years of Physical Science study and hours per week spent studying (positive predictors).

In addition Astin, (2005:8) also identified demographic predictors, such as:

iii) The father's level of education.

iv) Religious affiliation (Astin tested Jewish students who were all successful in completing degree studies).

v) Female students (more successful).

vi) Ethnicity (according to Astin, White students had a more likely chance of completing degree studies).

Personal characteristics found by Astin (2005:9) to influence degree completion positively are as follows:

- Emotional health.
- Attending religious services.
- Doing volunteer work.

Finally, Astin (2005:8) is confident that engaged students (involved with the community and other activities) prove to be more successful. In a recent study by Van Zyl (2009), students involved in campus and academic activities, with peer students and the community were more successful in studies.

Universities will be interested in prospective students who have the ability to succeed in their studies (Murphy & Davidshofer 1998:394). Although institutions will be competing for the best students nationally, students also base their decisions on various institutional attributes.

### 3.5.2 National trends

Cognisance of the significant difference between access into foreign institutions and South African Higher Education is important. Abroad, the majority of potential students is adequately prepared when applying for Higher Education (Hay & Marais 2004:62). National research on general ability and achievement testing conducted by Rademeyer and Schepers (1998:33-40); Lotriet *et al*. (2002:37-45); Claassen *et al*. 2004:82-92), Huysamen (2002a:139-147 & 2002b:111-128) and Maree (2003a:19-25; 2003b:61-68; 2009:279-297), Eiselen and Geyser (2003:124 ) and Foxcroft and Stumpf (2005:12), with various groups, indicate that school-leaving results were the best predictor for success in Higher Education. The learner who achieves well at school level has usually acquired the required discipline and learning strategies to succeed in Higher Education. As such, school results are predictors of successful academic achievement.

Rademeyer and Schepers (1998:34), propose that the use of school-leaving results in conjunction with psychometric tests will reveal good assessment of potential. They have evidence that the predictability, based on school results only is low for especially South African Black students. Foxcroft (2009), reiterates that the admission of first-year students, based on one instrument only (Grade 12-results) is a risk for Higher Education. Rademeyer and Schepers (1998:34) remark that the importance of general mental ability as a predictor decreases with prolonged further studies, and they emphasise the increasing influence of non-cognitive constructs in later studies. Lourens and Smit (2003:169) researched different trends in South African Higher Education. They found that unsuccessful students who ultimately withdraw from studies mainly constitute a mismatch between the choice of study field, financial difficulties and poor student experience.

Maree (2003a:22) conducted extensive research on Mathematics and school achievement. In 2003 he found that school results (cf. Table 3.3) might be an indication of first-year potential, but that it rarely predicted retention successfully. In reaction to the Trends in Mathematics and Science Study (TIMSS)-report of 2003, Maree (2003b:61-68) comments that the South African learners experienced difficulty with analysing tables, figures and illustrations. Other problem areas were calculations requiring more than one step, and word problems. Fractions, and any calculation involving the application of Geometry to determine the location of an area, were difficult for South African learners. In an analysis of the preparedness of first-year students in Mathematics in 2009, Engelbrecht *et al.* (2009:294-297) found that they were under-prepared in exponents, logarithms and the interpretation of graphs. If achievement tests include the above 'problem areas', the distinction between the profiles (potentially successful and at-risk students) may be valuable.

The fact that learners experienced problems with language proficiency (English) in the TIMSS (2007:1) emphasises problems in South African schooling standards. Maree (2003b:61-68) reports that South Africa achieved a TIMSS rating of 38$^{th}$ out of the 38 countries participating in the project. "Difficulties with the medium of instruction are undoubtedly a contributing factor to poor achievement, and impact on success and throughput rates" (MacGregor in University World News 30 Augustus 2009:1). In a report by Foxcroft and Stumpf (2005:15) there is indication that teaching in a second language contributes to poor achievement. South African students (and learners) require extensive support for language development, as well as quantitative and mathematical literacy.

First-year students are seldomly aware of their personal strengths and weaknesses and their ability to integrate into an institution. In South Africa, students usually select institutions rather than institutions selecting students. Students also rely on peers and family to make their choice of institution (UJ 2009c). Financial difficulties, the academic rating of institutions and selection procedures may also influence decisions (co-determinants when students select an institution).

#### *3.5.2.1 The Stellenbosch University Access Test*

In the last ten years most South African Higher Education institutions have become interested in the advance identification of successful students. Relevant research has been conducted in collaboration with the Stellenbosch University (SU), where the Access Test has been applied from 1995. This Access Test was developed from a diagnostic test battery (1998 to 2004) to an admission instrument (from 2005) and provides additional information on applicants. The test battery (cf. Table 5.6 and 5.7) is developed and maintained by a team of academic support specialists at the university, content specialists in academic departments and school teachers (Botha, Du Plessis & Menkveld 2007:14).

The Access Test of Stellenbosch University also measures skills and abilities, but is contextualised for the multi-cultural, multi-lingual and multi-ethnic South African society. The test is a criterion-based norm and was developed specifically for Stellenbosch University students. It consists of generic and content-specific testing (Botha *et al*. 2007:14). Prospective students complete a test in Academic Literacy (English and Afrikaans), in order to determine generic language and thinking proficiency. Students interested in Economic and Management Sciences – as well as Social Sciences - must complete a Numeracy Skills test in conjunction with the Academic Literacy test. Students in Economic and Management Sciences also complete a Mathematical test, which is a requirement for Science students. In addition, Science students write a Physical Science test. These are achievement tests and count 40% towards access. The remaining 60% is made up from the Grade 12 school examination results.

Huysamen (1997:67) states that proficiency test measures current competence and can be used as an aptitude test if designed to predict future achievement. In the case of the SU Access Test, Nel and Kistner (2009:953-973) make a strong argument for the inclusion of an additional measuring instrument to be applied in collaboration with Grade 12-results (Botha, Du Plessis, Kistner and Nel 2008).

#### *3.5.2.2 The AARP Test of the University of Cape Town*

The Alternative Admissions Research Project (AARP) was established at University of Cape Town (UCT) in the late 1980s, its primary purpose being to identify students, who might be successful in their studies, for admission. The aim of the project is to provide a selection and testing service and collaborate in developing related policies (UCT 2002). The test battery consists of an English language-based academic test comprising the following:

- The Placement Test in English for Educational Purposes (PTEEP): This test assesses the ability to make meaning of texts (at the level required for Higher Education); to understand words and discourse signals in their context; to identify and track an academic argument and to evaluate the evidential basis of the argument. The PTEEPT also assesses the ability to extrapolate, draw inferences, and understand visual information and basic numerical concepts.
- The Maths Achievement (MACH) Test: MACH measures the extent of the backlog in school mathematical knowledge and skills.
- The Maths Comprehension (MCOM) Test: Designed to provide information on the potential to acquire new mathematical knowledge and skills. Abilities are tested in comprehension of concepts, analysis and synthesis of principles, and translating information.

The UCT AARP Report (2002:13-15) concludes that predictive validities embedded in the test battery are meaningful to apply within determining the profile of students.

*3.5.2.3 Other tests*

Other tests in South Africa are the Tertiary Education Linkages Project (TELP) and the Standarised Assessment Tests for Access and Placement (SATAP), to mention but two. Grussendorff *et al*. (2004:265-272) provide insight into the difficulty and costs involved in testing learning potential and the fact that such testing also relies on prior learning and experience. This study argues that tests specifically designed for a particular purpose will allow for access as well as success. The use of a Science Foundation Programme (SFP) to utilise the additional support to remedy any under-preparedness has proven to be successful at one specific Higher Education institution. At another university, a Chemistry test developed specifically to evaluate placement decisions (Potgieter, Davidowitz and Venter 2008:1-18), provided meaningful information to identify under-preparedness for remedial support.

The National Certificate (NC), awarded in South Africa up to 2007, and discussed previously, provided the Higher Education sector with information on which to base admission decisions. Access for Black students with low aggregates and disadvantaged educational conditions and backgrounds has been discussed widely. Care should be taken to avoid the ‘revolving door’ syndrome of students entering and leaving without any success (Dawes, Yeld & Smith 1999:97-104; Huysamen 1997:65 and Foxcroft & Stumpf 2005:10-32). Management of the admission process as a separate entity is not advisable for Higher Education in South Africa. Admitting under-prepared students into Higher Education implies careful management to ensure success (cf. Chapter 2.4).

Higher Education South Africa (HESA) has expressed concern about the shortage of students who can read, write and comprehend adequately. "Less than a half of first-year students have the academic literacy skills needed to succeed without support" (HESA 2006:1). The sector is used to perform some testing, and HESA commissioned the National Benchmark Test (NBT) Project in 2005 to supplement the new school-leaving examinations (HESA 2006:1). This test is available to every Grade 12-learner in South Africa at a very affordable price and was piloted in 2009 (Beeld 13 August 2008c:12 & Yeld 2009a).

*3.5.2.4 The National Benchmark Test (NBT)*

The definition of "benchmark" refers to evaluating and monitoring the adequacy learners' of achievement and educational development of learners (HESA 2008:7). The achievement standards are providing the Higher Education sector with the expected level of attainment of the stated learning outcomes. It is important that all learners achieve the outcomes in certain grades or at desired levels. According to the HESA definition (HESA 2008:11), the NBT assesses achievement with respect to learning outcomes in a specific domain. These are measured against a continuum of expected levels of minimum proficiency, developed for a specific purpose.

The three core areas evaluated in the NBT are Academic Literacy, Quantitative Literacy and Mathematical literacy (see Table 3.5 with more detail). According to HESA (2008:5) the two assumptions underpinning the NBT are:

- School-leaving results reflect knowledge, skills and applied competencies inaccurately. The results are an inadequate reflection of potential and, in order to select and place students fairly, additional assessment is required.
- Higher Education requires an understanding of the preparedness and level of entering students, in order to determine the educational task that must be fulfilled.

The fact that the NSC has not yet been benchmarked against any comparable qualification should also be considered.

The NBT aims to provide additional information about achievement in core as well as underlying areas, in addition to Grade 12 (NSC)-results. At a colloquium held in 2009 in Cape Town, Yeld (2009b) explained that there was a fundamental difference between the NSC examination (in terms of design procedures), and the referenced standardising and resulting processes of the NSC. For the purpose of the NBT:

- All test items should have been reviewed rigorously in terms of fairness, content, bias and others.

- Test items need to be statistically robust.
- It is not about whether students pass or not; it serves as a benchmark.
- The process is based on a set of probability assessments.
- Yeld (2009b) identified the core issues as follows: Students unable to pass or achieve will experience academic difficulties in Higher Education. The test results will be able to indicate the severity of identified problems.
- The benchmarks may seem low, but they indeed 'match' the knowledge and experience of the majority of students in the system.

Yeld (2009b) quite correctly states that all role players in South African Higher Education experience academic struggle, resulting in slow throughput and high failure rates. The NBT was developed in three steps (HESA 2008:11), namely: the planning phase, followed by, field testing and psychometric evaluation. Finally, the test will be reviewed continually before being finalised. The Centre for Higher Education Development (CHED) at UCT was mandated by HESA to manage the NBT-project.

The NBT only indicates prior content knowledge and skills. It does not measure potential or educational and socio-economic background. Yeld (2009a) states the following non-negotiable requirements, as perceived through her experience and research in Higher Education:

- Advanced level Mathematics and Physical Science are required for studies in Science, Health Sciences and Engineering.
- Students require a level of academic literacy (the ability to structure ideas, construct an argument and think logically) and proficiency in the medium (language) of instruction.

Yeld is positive that NBT-results in Mathematics and Academic Literacy will be valuable for Higher Education, from 2010 onwards (Yeld 2009b). As stated above, three core areas are evaluated by the NBT. Table 3.5 provides information on the components of the NBT:

**Table 3.4** ***The Components of the NBT***
(Adapted from Yeld: 2009b)

| Test component | The purpose of the test is to determine: | Duration of test |
|---|---|---|
| Academic literacy | Students' capacity to engage successfully with the demands of academic study in the medium of instruction. | } One 3-hour test |
| Quantitative literacy | Students' ability to manage situations or solve problems of a quantitative nature in real contexts relevant to Higher Education | |
| Mathematics | Students' ability related to Mathematical concepts that form part of the NSC Mathematics curriculum. | One 3-hour test |

The evaluation scale was initially divided into three categories, namely: i) Proficient, Intermediate and Basic achievement. The project team later divided the Intermediate scale to ii) a "top" intermediate and iii) a "bottom" intermediate to refine this category. The table below (3.6) indicates the norms and categories with implications of each.

**Table 3.5** ***Rating of the NBT***
(Adapted from Yeld: 2009b)

| Scale | Rating | Indication of achievement | Implications for HE |
|---|---|---|---|
| **100%** | Proficient | Achievement indicates that the student is competent and capable of passing. | Place the student in a regular degree programme. |
| | Intermediate | Achievement indicates areas that will be affected. Identification of problem areas. | Placing the student in a regular degree programme might be a risk. Provide additional support. |
| **0%** | Basic | Achievement indicates serious learning challenges. Predictions are that the student will not cope. | Place the student in a bridging or extended degree or diploma programme and provide additional support. |

The 2009 cohort of first-year students was the first group with the NSC to enrol at South African Higher Education institutions. In 2009 the NBT project team conducted a pilot study involving 13 000 first-year students already enrolled in South African Higher Education institutions. The universities that joined this investigation were: UCT, UWC, Mangosuthu, Rhodes, SU, UKZN and Wits. The majority of these students did not complete the NBT prior to admission and were already admitted into academic programmes at the relevant universities. This study provided the following results:

- Only 7% (of the 11 542 participants) tested as proficient for university studies (Beeld 13 August 2009g:2).
- 73% of this group would require additional support and tuition in Mathematics.
- The problems already began during the foundation phase, including the fact that the language of teaching and learning was not the home language (cf. Section 3.4.1.3).

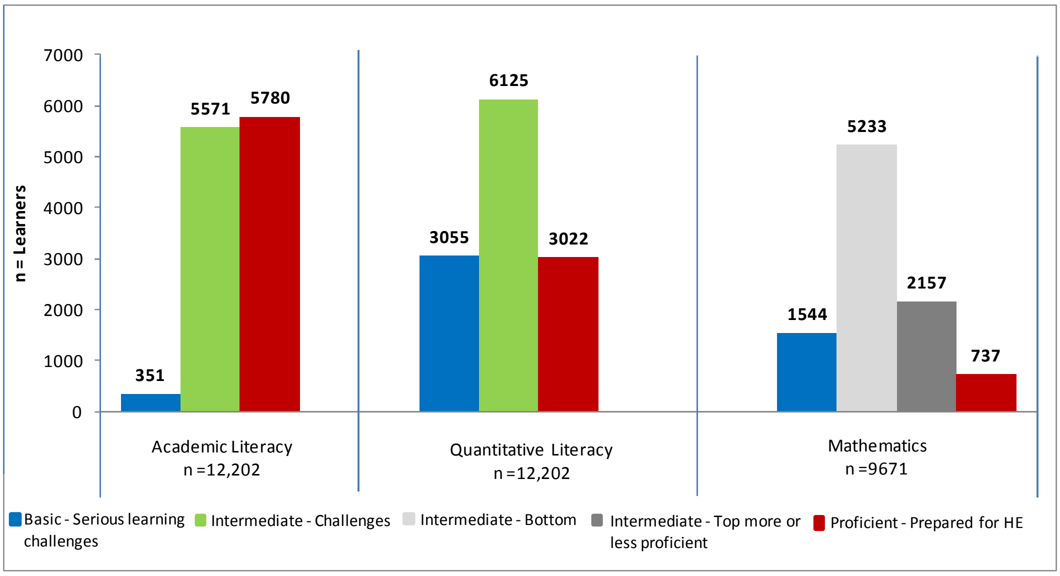


***Figure 3.9*** **Achievement of the 2009 pilot study in the three components of the NBT**
(Adapted from Yeld: 2009b)

In Figure 3.9, the results of the pilot study conducted in 2009, are represented in a graph. Of the 11 542 participants, 24% (n=2742) were enrolled for Engineering, 5% (n=535) in Health Science programmes, and 21% (n=2503) in Sciences. The remaining 50% constituted Law (3.3%), Education (1.9%), Humanities (12%) and Commerce (33%). When measuring Academic Literacy, 3% achieved basic and 48% intermediate scoring. Only 49% (n=5780) scored in the proficient band of Academic Literacy. Only 24.8% of students tested as being proficient in Quantitative Literacy, while 50.2% fell in the intermediate band.

Commerce and SET students are required to gain admission, based on their Mathematics performance. Nevertheless, worst results were evident from the Mathematics test. Of 9 671 students, 16% had serious learning challenges in basic Mathematics. When dividing the intermediate score into two groups, namely bottom and top intermediate, 54.1% of the students fell in the bottom intermediate (challenges identified). The top intermediate (22.3%) can be successful, with additional support and interventions. This leaves 7.6% of students in the proficiency band, implying that only 737 of them are sufficiently prepared for Mathematics at Higher Education level.

Yeld (2009a) concludes that either the NCS-Mathematics is set at too low a level (similar to the Standard Grade of the previous system), or NBT-Mathematics is too complicated. Nevertheless, she proposes that the NBT can act as a ‘watchdog’ regarding NSC-standards. Even if NBT-Mathematics is not too complicated, there would still be an insufficient number of students in the top intermediate who could cope with the expected competency level in Higher Education. Specifically Mathematics teaching and especially in Grade 12 as a whole therefore needs serious attention. The entire curriculum must be taught, in order to prepare learners for further studies.

In a final comparison, Yeld (2009a) analysed the Grade 12 final Mathematics results in terms of the NBT-Mathematics test results. In the graphical presentation in Figure 3.10, the Grade 12 NSC-results are indicated. The NBT-Mathematics results indicate that Grade 12-results of between 80% and 100% represent mostly intermediate level with a few proficient achievements. Even students with only basic Mathematics competency were awarded Grade 12-results above 80%. Students with Grade 12-results of between 70% and 80% are mainly in the bottom intermediate group, while all candidates below 70% and above 50% show a tendency to achieve basic results in NBT.

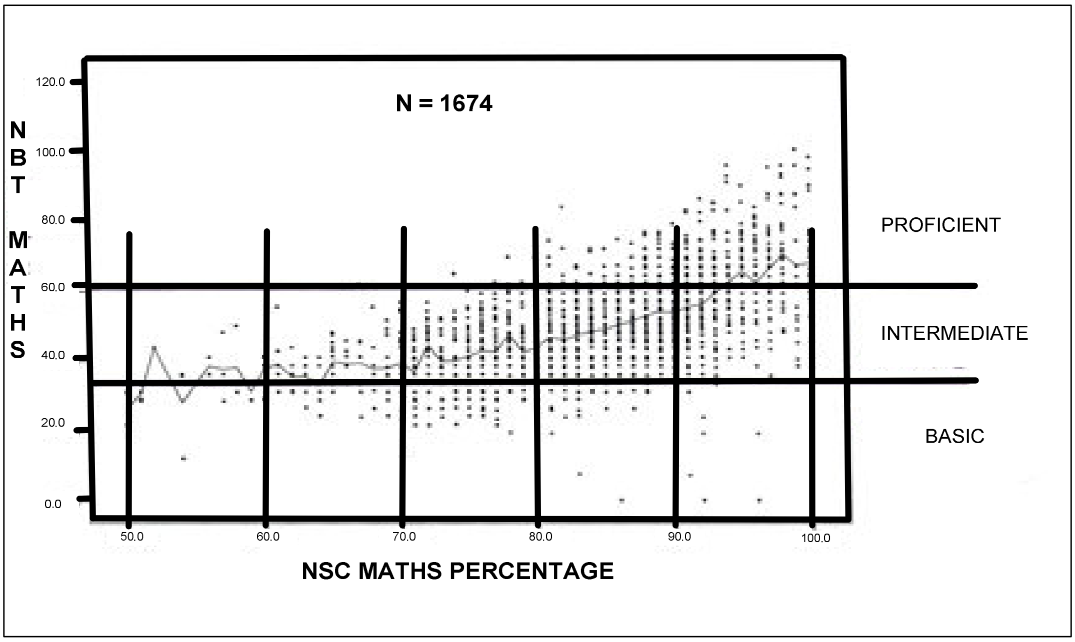


***Figure 3.10*** **The presentation of NBT pilot results (2009) and Grade 12-results in Mathematics in 2008**
(Adapted from Yeld: 2009a)

The above poses serious implications for universities when determining admission requirements. If students have a good predicted chance to pass at Higher Education with 80% for Grade 12 Mathematics, that should be the admission requirement. If universities admit students with 60% in Grade 12 into Mathematics modules, they have almost no chance of passing first-year Mathematics. Is this fair practice? The vice-chancellors of leading South African Higher Education universities point out that NBT-results are the reality and "…you can see the general findings. Not good" (The Star 11 August 2009:4).

HESA is serious about implementing the NBT, but school education specialists are sceptical of whether it is a credible test. Directors-General of the DoE are defending their standards, but need to be convinced of what the use of the NBTs would be if the NSC were the official school-leaving examination (Umalusi 2009). Criticism of a South African admission test is similar to international concerns (bias and coaching). Experts agree that exclusion of students with potential will affect access negatively (Huysamen 1997:65) and that assessment of past instruction and experience would be an achievement test that would clearly indicate the deficits and inequalities South African schools currently in the OBE system.

*3.5.2.5 Additional factors to be considered*

In the South African context, the following additional factors should be considered when developing achievement tests:

- First generation students: According to University World News (28 July 2007), 70% of South African students have no siblings with university experience. Such students are considered to be first-generation students.
- Public understanding of Science: A study performed by Blankley and Arnold (2001: 65-69) indicated that over 30% of adults in SA had never studied Mathematics, 50% had never studied Biological Sciences, and 55% had never studied Physical Science.
- Teachers: The pool of potential teachers in the aforementioned groups is limited if all the other Science study fields draw upon prospective students first. In a study on the achievement of first-year students, the quality of teachers in Mathematics and Science contributed to a crisis situation regarding these modules.

Professor Brian Augustine (from the USA) visited a SA Higher Education institution and taught first-year Chemistry in 2009 (The Star 11 August 2009:3). He commented that 50% of the students "…don't have the basic Science, maths and literacy skills needed to compete at university level." He also expressed concern about the third-year class, which would barely pass, due to a lack of previously acquired knowledge in understanding nano-Science. This concern was reiterated by Prof. Howie from UP (The Times Higher Education Supplement 25 July 2009:1): "It looks like we're giving people a chance, but what we're giving them is an opportunity to fail." Augustine proposed an entrance examination by means of which students who needed 'catch-up' could be identified. This can be instituted by means of a five-year degree, where two years will be spent focusing on school Mathematics, Science, academic literacy and language proficiency. Students will also have to prepare by reading journal articles and writing laboratory reports. Providing society with well-rounded graduates would mean careful placement of students as performed internationally.

### 3.5.3 Admission and placement testing

Admission testing is common practice internationally. In the USA, almost 2.6 million of the 3 million high school graduating students write one of the aforementioned tests annually (cf. Section 3.5.1). According to Scholtz and Allen-ile (2007:922), it takes a generation or two to establish a culture of informed applicants and parents who consider such tests seriously. Proficiency testing has been taking place nationally, mainly to place students in the first year of Medical, Nursing and Engineering schools. In SA, a Health Sciences Placement Test (HSPT) has been used as an additional admission tool for studies in Health Sciences for many years (Van der Merwe, Mouton and Botha 2000:34-38). At Wits, the HSPT counts 40% towards admission, NSC results 40%, and 20% is awarded to factors such as suitability for the profession (The Times Higher Education Supplement 25 July 2009:1). For admission into Art and Architecture students must submit a portfolio presentation, but in most other academic programmes there are no formal admission tests.

Research indicates that predictions based on Grade 11-results are not more reliable then Grade 12-results. Huysamen (1997:69-70) provides a list of the challenges and measures to take into account when developing admission tests. Test security, legal matters and governance surrounding psychometric testing, are dealt with at high levels. Coaching has developed into a profitable business in the United States of America, where students are able to buy books with the questions and answers and can attend classes to ensure a pass or improvement. A similar system in South Africa will create major inequalities.

A closer look at "bridging-the-gap" between school and university prompted Hay and Marais (2004:59-75) to reveal the following:

- Many institutions admit under-prepared students into bridging, foundational or extended qualification programmes, mainly retaining standard content and teaching methods, for another specialised unit to provide the required remedial support.
- The attitude is perpetuated that only students should be modified, not the course, institution or teaching approach.
- Students must adjust to the course content and are not accommodated in remedial education.
- Most bridging courses are add-ons without credits towards a qualification, and not subsidised by the government.

Admission testing will only be meaningful if it can successfully distinguish between potential graduates and individuals who should not pursue Higher Education. In a summary of core competencies for Higher Education entry, Foxcroft and Stumpf (2005:12–16) and Scholtz and Allen-ile (2007:919) identified core admission requirements that could be indicators within admission tests (see Table 3.6). If these attributes are required for successful studies, a test or instrument should be developed to assess such attributes in students. The NBT-battery will possibly be able to indicate reading, mathematical and scientific literacy. It can determine knowledge of Mathematics, but none of the other attributes in Table 3.6. Non-cognitive attributes will manifest in the academic literacy test (of the NBT), however not as detailed as required by Foxcroft and Stumpf (cf. chapter 4). The aim of admission testing is to determine an applicant's ability to achieve at a specific level in a focused discipline at a given time (Scholtz and Allen-ile, 2007:919). Completion of the NBT in Grade 12, before admission into Higher Education should be done at an appropriate time, as potential applicants will be preparing for their final school assessment.

**Table 3.6** ***Attributes Required for Successful HE Admission***
(Adapted from Scholtz and Allen-ile 2007:919; Foxcroft and Stumpf 2005:12–16)

| Cognitive attributes | Non-cognitive attributes |
|---|---|
| **Learners at exit school level should show a predetermined level of the following cognitive attributes, to succeed in HE:** | **Learners at the exit school level should have a predetermined level of the following non-cognitive attributes to succeed in HE:** |
| 1. Reading, mathematical and scientific literacy. | 1. Commitment, values and attitude towards study. |
| 2. Information literacy (library, research methods and technological skills. | 2. Independent thinking, creative and original thinking skills. |
| 3. Cross-cultural problem-solving skills. | 3. Intellectual curiosity and interest in ideas. |
| 4. A required depth of knowledge in core subject requirements. | 4. Disciplined work habits and ability to work in teams. |
| 5. Communication (reading, writing and presentation) skills. | 5. Enthusiasm for learning and willingness to explore and question. |
| | 6. Motivation and self-confidence |

This study proposes that an assessment before admission will strengthen admission and enrolment decisions. Care should be taken not to exclude students with potential, and support and additional interventions must be in place when enrolment commences. The importance of achievement measurement of Mathematics and Science can never be under-estimated. Students might show high potential, but if achievement and prior knowledge and skills are lacking, they will only be successful with responsible placement. The identification of at-risk students within the first three weeks will also assist placement in appropriate programmes. The advantage of a pre-admission test as a diagnostic instrument to identify remedial areas that can benefit from support is crucial.

## 3.6 SYNTHESIS

This chapter probed general mental ability and its distinct role in academic achievement. The structuring of 60 narrow specific abilities (Stratum I) into eight broad abilities (Stratum II), with all of these abilities constituting general mental ability (g-Stratum III), represents the CHC-model (cf. Section 3.3). General mental ability enables students to solve problems, to learn and to reason, also referred to as high intelligence.

Learning takes place when information is processed. According to Bloom's taxonomy, the application of general mental ability and acquisition of knowledge can be measured at six different levels of complexity. An adapted version of this taxonomy commences with remember, then understand, moving to applying knowledge, analysis and evaluation and, finally, creation of own knowledge. In this sense, this study focuses on learning in Higher Education and emphasises on higher order thinking that clearly requires general mental ability.

Higher order thinking, manifested in general mental ability, is imperative for achieving in Mathematics and Science. Mathematics and Science are regarded as an important gateway to studies in Science, Medicine, Engineering and Information Technology. There is status attached to achievement in Mathematics and Science, and these disciplines provide an opportunity to understand the world we live in. Although South Africa requires a population with mathematical and scientifically literate citizens, the education system does not fully support this requirement. Under-prepared teachers produce under-prepared learners; resulting in these under-prepared learners becoming unsuccessful students - a situation South Africa cannot afford any longer.

A change in school-leaving assessment in 2008 resulted in excellent school pass rates, with shocking consequences when the learners entered Higher Education. The language of teaching and learning is also alleged to impede achievement in Mathematics and Science. Students are equipped with technological abilities, but are not sufficiently prepared to enter the Higher Education sector. Many students fail their first year of study and lose confidence, while the pool of scientists, Science teachers, Engineers and Medical practitioners diminishes. The Higher Education system can assist under-prepared students if their deficits are known. Early identification, diagnostic profiling and responsible placement can take place, with knowledge provided by student profiling (cf. Section 7.5). Knowledge of general mental ability can provide information to determine potential. Previous academic achievement adds to student profiles, and measurement of content knowledge and skills enables Higher Education to assist students with their course selection and, therefore, placement. Current NBT-results can provide valuable additional knowledge and should inevitably become compulsory as an instrument to assist placement in universities.

The placement of students to achieve academic success in specifically Science programmes depends on general mental ability and prior knowledge of Mathematics and Science. The following characteristics may inform placement of students: Students with a high standing in general mental ability are able to deal with complexities, required for Science studies. Secondly, IQ testing (measurement of narrow abilities) provides an indication of potential as a gauge of academic achievement. Thirdly, abstract thinking and problem-solving are fundamental skills for Science studies. Finally, the NBT-results can be applied to indicate prior knowledge base.

In conjunction with the abovementioned attributes, the research findings reported in this chapter emphasise that high order thinking skills build on low order cognitive levels. The latter must be embedded to lay a solid foundation for Mathematics and Science learning. Furthermore, the proficiency tests (NBT) measure mastery of specific content and reflects quality of schooling. These above factors should inform the development of a framework for placement. In addition, the need for qualified and competent Mathematics and Science teachers in South Africa necessitates a review of the entrance level of first-year curricula. No longer can lecturers rely on a school foundation and proceed from there. They should begin with school content and teach their discipline with passion and well equipped resources for students to learn and develop a passion for Mathematics and Science.

Differentiation of students entering at different levels and with diverse skills is possible in smaller classes, with well planned academic support. Tutor and mentor groups in various language groups can provide students with a safe environment to ask questions and clarify new concepts. Another consideration for the framework for placement is that the careful selection of staff who will be working with first-year students will render dividends. Lecturers with appropriate teaching qualifications and experience will be able to assist students with their adjustment from school to Higher Education.

Considering all of the above, it is the opinion of the researcher that institutions should not exclude students with potential and an interest to study Science. This does not imply that all students should be placed in degree courses and that all of them should pass in a given year. Some students may take longer to adjust but could still be successful. Others may be better equipped to study diploma qualifications. Students will not know this. The specialists are current lecturing staff at universities, who know which students will be able to pass, and which students should rather pursue another field of study to be able to accelerate and be successful. The problem encountered by these lecturers' results from their lecturing to such large groups of students that they never find an opportunity to get to know students and to really engage with them.

The next chapter will include a literature study on non-cognitive attributes, specifically personality and self-efficacy, motivation, interest, and teaching and learning, as components of academic success in Higher Education. These non-cognitive attributes will have to be considered if students are provided with an opportunity to succeed.

# CHAPTER 4

# *NON-COGNITIVE INDIVIDUAL DIFFERENCES AND ACADEMIC ACHIEVEMENT*

## 4.1 INTRODUCTION

The previous chapter probed the influence of general mental ability and prior knowledge on academic achievement at university level. These attributes co-determine first-year student achievement in Science programmes. In this chapter discussions on non-cognitive individual differences and its impact on academic achievement will follow. Firstly, the chapter discusses individual differences with a focus on non-cognitive attributes. Secondly, the chapter presents the Basic Trait Inventory as an instrument for personality profiling. Thirdly, the role of motivation, interest, teaching and learning and self-efficacy in academic achievement are contextualised via a deliberation of relevant studies in the unique South African context.

This chapter focuses on the role of non-cognitive abilities and attributes through the lens of achieving in gateway modules in Science, namely: Mathematics, Physics and Chemistry, as generic first-year modules. Figure 4.1 provides an outline of this chapter. It serves as a model to indicate identified non-cognitive attributes and its influence on student academic achievement in Science. The hexagonal centre has six borders, each representing the six attributes that will be discussed.

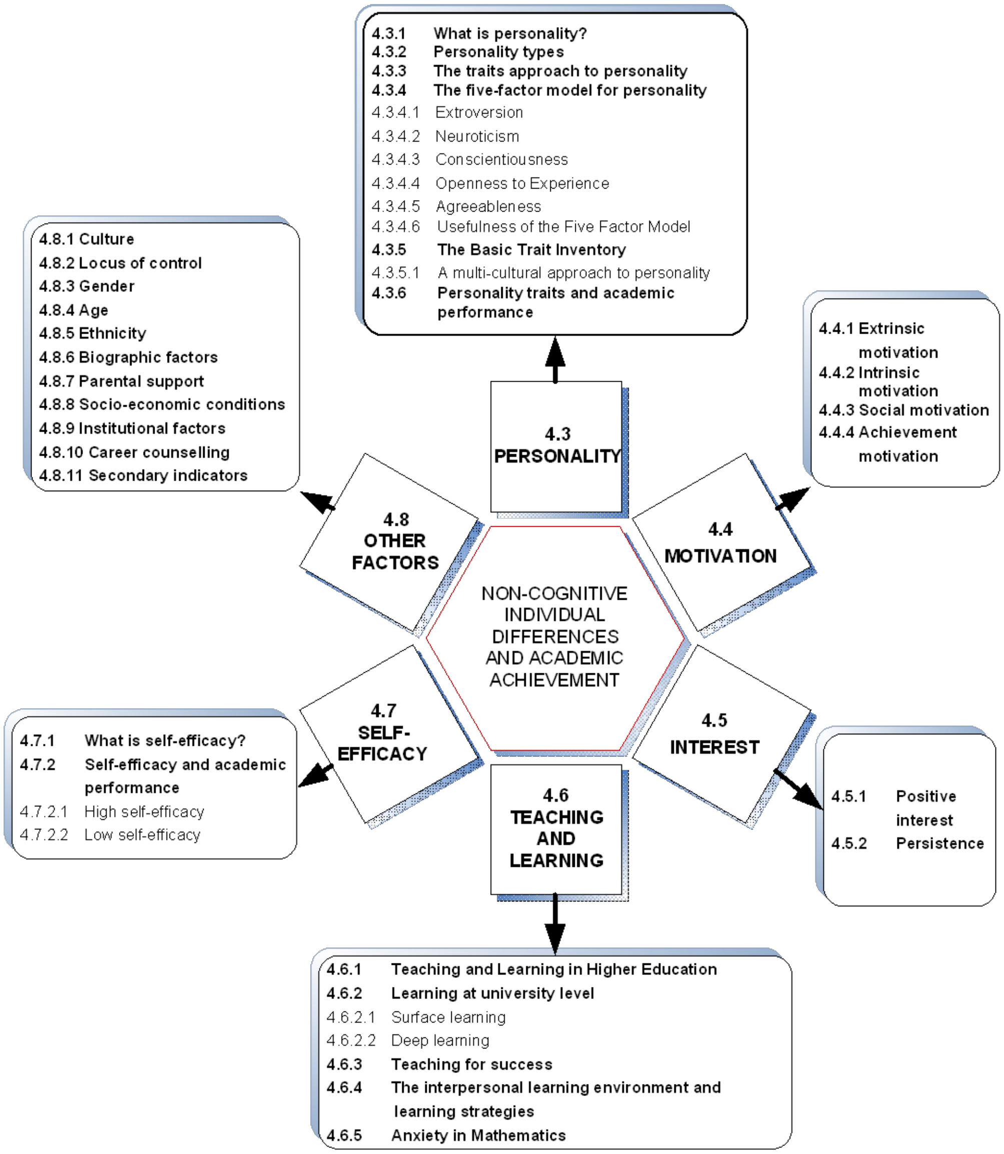


***Figure 4.1*** **Non-cognitive individual differences and academic achievement**

## 4.2 INDIVIDUAL DIFFERENCES

Individuals will behave similarly or differently in specific situations, and this is also true for the way they think, react or manifest their feelings. Maltby, Day and Macaskill (2007:418) explain that the term “individual differences” is used to explain why an individual may not necessarily fit into a particular theoretical category. Many psychological perspectives and theories generalise and place individuals into classes. In reality, individuals act differently in every specific situation. They differ in personality and experiences, as well as societal constructs, and these attributes influence their actions and behaviour. This study acknowledges the fact that individual differences exist and will influence academic achievement.

As discussed in the previous chapter, academic success often relies on general mental ability and prior content knowledge. Academic achievement, such as obtaining an appropriate qualification, implies that a particular level of general mental ability exists in every individual. Holland (1997:98-155) indicates that the modern trend is to assess personality in many job-profiling tests. Such an evaluation might provide useful information (in addition to qualifications and major interests) about applicants. There is however, little evidence that any non-cognitive attribute is currently applied in the selection and admission of students for university studies. The next discussion will therefore shed some light on personality as an indicator of academic success at university.

## 4.3 PERSONALITY

This section discusses the first non-cognitive factor that can possibly be associated with academic achievement, namely personality. The diagram below presents the flow from a general investigation of personality to a focus on the five factor model (Figure 4.2).

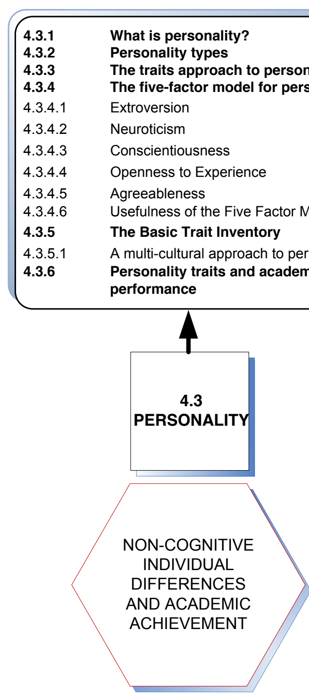


***Figure 4.2*** **Personality and academic achievement**

The influence of various personality traits on academic achievement has been proven by researchers worldwide. Extensive research in the South African context by Van der Merwe and De Beer (2006:547), Van Rooyen (2001:181), Rademeyer and Schepers (1998:33) and De Bruin (2000:12), among others, provides sufficient evidence of the consistent correlation of personality and successful learning. Students in the field of Natural Sciences, Humanities and Commercial Sciences will manifest specific common behaviour, resulting in stereotyping such students. The abovementioned researchers are confident that fitting into a profile is 'normal'. A brief look into the various personality types will follow the initial discussion on what personality entails.

### 4.3.1 What is personality?

According to Oxford Advanced Learners Dictionary (2010:1093) 'personality' can be defined as "the various aspects of a person's character that combine to make them different from other people". Several variables must be considered before defining 'personality' within the context of this study. Murphy and Davidshofer (1998:39-40) make three statements, in order to simplify the process of defining personality. Firstly, the uniqueness (no two individuals being exactly alike in terms of behaviour, preferences and temperament) complicates the formulation of a single definition. Secondly, it is known that individuals do not behave identically in a given situation. Thirdly, "…there is always a considerable commonality in human behavior".

Allport (1961:28) describes personality as a "…dynamic organization within the individual…" indicating that, while development and growth is possible, the dynamics will be organised. According to Eysenck (1970:2), "Personality is the more or less stable and enduring organisation of a person's character, temperament, intellect, and physique, which determines his unique adjustment to the environment". Cohen and Swerdik (2009:379) explain personality as distinguishable (implying being different to other) in a specific context, determining a unique pattern of behaviour. Their definition of personality is "…an individual's unique constellation of psychological traits and states."

This research will adopt the statement by Cattell and Cattell (1995:928), namely that a consistency exists in the personality attributes in different contexts. Consequently, the following is the preferred working definition (according to the researcher) for the purpose of this investigation: Personality, as defined by Murphy and Davidshofer (1998:40), is "… the set of characteristics of a person or of people that account for consistent patterns of response to situations." Traits, on the other hand, are relatively permanent (and consistent) tendencies, constituting the basic structural units of personality.

Although detail will differ, humans show similar behaviour patterns and it is therefore possible to classify them meaningfully. There are various ways of approaching personality, with every angle indicating a specific stance about this complex phenomenon. For the purpose of this study, it will be necessary to pursue the field of personality psychology to compare different definitions.

According to De Bruin (2000:78-79), personality can be perceived through five different psychological lenses:

i) The psychodynamic perspective bases a theory on the premise that a set of internal thrusts either work together or are in conflict with each other. The unconscious therefore plays a role in behaviour.
ii) Behaviourism focuses on human behaviour, as being integrated with all human experiences.
iii) According to the biological approach, genetics and complex biological systems guide personality.
iv) According to the phenomenological perspective, every individual will have a unique subjective meaning and choice of personality.
v) The traits approach assumes that behaviour, thoughts and feelings are relatively stable and consistent over time, and are determined by traits.

This study will approach personality by describing personality types (e.g. Realist or Investigative). Next, personality traits will be considered thus exploring the characteristics possessed by individuals, to predict academic success. The Basic Trait Inventory (BTI) as an instrument to determine the dominant trait present will then be discussed. Finally, other variables that influence academic achievement will be discussed.

#### 4.3.2 Personality types

Theories on personality developed after World War 1, when placement and selection for the military were based on the results of personality assessments and profiles. Various instruments and techniques were developed, and relevant inventories used to measure facets of personality. This research will only refer to the personality type model of Holland (1997:38), as this particular model is straightforward and simple in presenting rather complex constructs.

Holland (1997:38) characterises people by their unique behaviour and consequent resemblance to each of six personality types. According to Holland's extensive study of human behaviour and conduct, individuals resemble a particular type of personality. The more the resemblance, the more that individual will exhibit personal traits and behaviour associated with that specific personality type. The personality and paired environment in which individuals live and work depict predictability in career choice, stability and achievement. Holland categorises personality according to dominant behaviour: investigative, social, artistic, conventional, enterprising and realistic (Holland 1997:38).

According to Holland (1997:3), the development of the different personality types is established by studying interaction in social, cultural and physical environments. The environment is influenced by both parents' personality types. Home, school and peers also contribute to the experiences and opportunities of the individual, thus developing self-concept, values and personality traits. Individuals prefer specific activities and will show an interest and competency in definite strands. The Holland-model identifies the dominant personality type of the individual but he/she might also resemble other types in a definite sequence. The six models allow for "…720 different personality patterns or repertoires for coping with that person's environment" (Holland 1997:3).

In the context of the hexagonal model and for the purpose of defining the psychological resemblance among personality types, the principles below need to be acknowledged (Holland 1997:7-11):

- The choice of an occupation is an expression of personality and a vocational interest.
- Interest inventories are signs of personality traits.
- Vocational stereotypes satisfy criteria of reliability and validity and are helpful in selecting a suitable occupation.
- Members of a vocation have similar personalities and respond in similar ways.

The above principles are relevant for assessing individual personality. For the purpose of this study, namely to predict students' engagement with education and academic achievement, the preferred personality type(s) are therefore important. The appropriate personality pattern consists of almost all the above characteristics at different levels and different sequences. For example, a combination of **E**nterprising, **S**ocial and **C**onventional will be labelled as an 'ESC' pattern. This provides a certain predictability or "tendency field" to interpret specific behaviour.

In the hexagonal model below (Figure 4.3) the correlation among personality types are inversely proportional to the distances among them. The line between Conventional and Artistic (red line) is the longest as; these two personality types differ considerably. Types adjacent to each other (compare the black lines) are closely related (e.g. Enterprising and Social). The distance between Enterprising and Realistic (blue line) is shorter than the connection (green) between Realistic and Social. The hexagon indicates the most suitable or congruent environment for a specific personality type. In a realistic environment the social person will be incongruent and feel uncomfortable (Holland 1997:17-40).

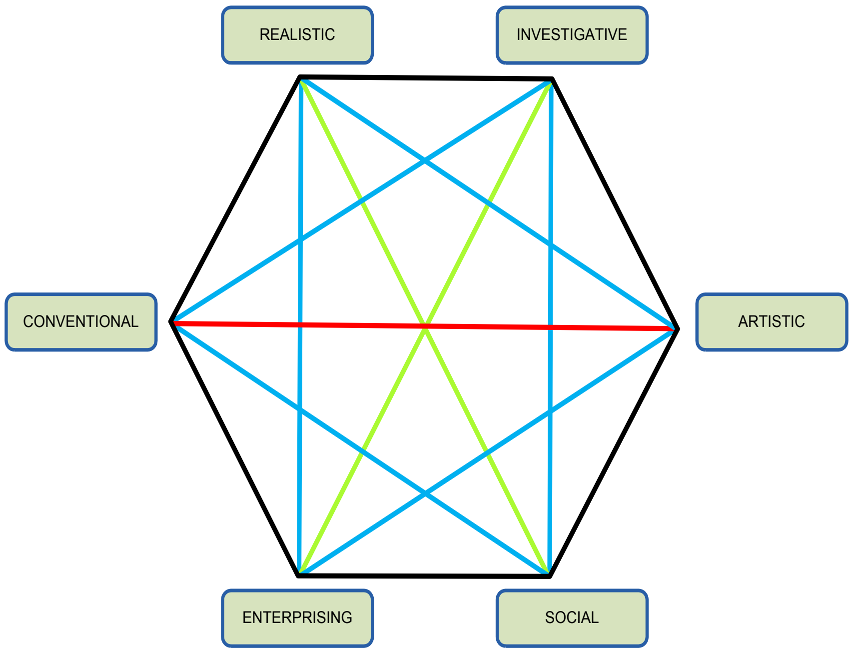


***Figure 4.3*** **The Holland hexagonal model for personality types**
(Adapted from Holland 1997:6)

This study investigates the personality types that would typically fit the profile of successful study in Science and related fields. For example, the Investigative type is appropriate for study in most Science disciplines (e.g. Biology and Chemistry). Holland (1997:38) states that investigation will resemble large portions of their behaviour pattern. Each personality pattern is dominated by one specific personality type (e.g. Investigative), as well as a second and third type, that will resemble a sub-group (indicative of a particular personality pattern, such as social-artistic). Holland (1997:39) proposes that a rank or order exists, depending on the required achievement. High educational aspirations will require the following personality pattern ranking: Investigative, Social, Artistic, Conventional, Enterprising and Realistic. This ranking will be advisable to cope with the challenges of studies in Science and related programmes.

The description of personality types is not only useful when selecting or predicting a field of study, but also to select an appropriate career. In a classification by Feldman, Smart and Ethington (1999:646), when fitting environments to personality types, the following types related to the majority of the Science-related occupations: Realistic (most of the Engineering disciplines), Investigative (Science and Medical fields) and Enterprising (Computer Science). Murphy and Davidshofer (1998:41), as well as De Bruin (2000:80), state that the traits approach has been useful as an indicator of academic success at Higher Education level. There is also value in establishing a biological basis for personality and social behaviour by engaging with the traits approach.

### 4.3.3 The traits approach to personality

A trait will be evident of a consistent structure of behaviour (De Bruin 2000:81), and describes a pattern of behaviour, for instance, honesty, an outgoing or empathetic action, and feelings. A trait would also be a description of expected future behaviour (under similar circumstances). De Bruin (2000:81) records that the ancient Greeks, Aristotle and Hippocrates, were progenitors of the trait approach to personality.

The traits approach provides an essential contribution to an objective determination of personality dimensions. De Bruin (2000:79-80) emphasises that this approach focuses on individual differences, and that many instruments are designed to measure such differences. Although two individuals may have similar characteristics, their reaction or behaviour in the same environment will most probably be different. According to Pervin and John (2001:251), differences might result from the fact that individuals have different experiences. In addition, psychophysical systems also contribute to the uniqueness of every individual.

McCrae and Costa (1991:367-372), formulated three fundamental assumptions of the trait approach to personality. One assumption is the consistency of behaviour in similar situations, with the second being the fact that traits are established by comparing individuals. The third assumption is that individual differences result from the different traits and intensities of traits that exist in individuals. McCrae and Costa (1991:367-372), and Pervin and John (2001: 252), define a trait as "...a disposition to behave in a particular way, as expressed in a person's behaviour over a range of situations."

For the purpose of this study, an elaborate literature study on the historical developments of the trait approach will not be pursued. The research of Allport, Eysenck, Cattell, McCrae and Costa will, however, is acknowledged (cf. Section 4.3.1). The Eysenck-model describes personality as consisting of three basic dimensions: i) introversion-extroversion, ii) neuroticism (emotional stability-instability), and iii) psychoticism (normal-psychotic continuum).

McCrae and Costa (1991:367-372) distinguish traits as dispositions deduced from patterns in the actions, thoughts and feelings of an individual. These researchers adhere to the personality model, consisting of three traits, namely i) Neuroticism, ii) Extroversion and iii) Openness to Experience. They subsequently propose the addition of Agreeableness and Conscientiousness, to constitute the Five Factor model.

### 4.3.4 The Five Factor Model of personality

This study attempts to link previous research to personality traits and the predictability of academic success. The Five Factor Model hypothesises that personality can be reduced to the "Big Five", namely **O**penness to Experience, **C**onscientiousness, **E**xtroversion, **A**greeableness and **N**euroticism (creating the acronym OCEAN). Among the most prolific modern researchers on the Five Factor Model are Robert McCrae and Paul Costa (McCrae & Costa 1991:367-372), who developed the NEO Personality Inventory (NEO-PI) in the early 1980s.

This instrument is based on factor analyses of the 16 Personality Factor Questionnaire (16-PF) (De Bruin 2000:87–88). McCrae and Costa later designed the Revised NEO-PI, a questionnaire specifically designed to operationalise personality in terms of the Five Factor Model. De Raad (1992:15-29), as well as McCrae and Costa (1991:367-372) identified specific traits aimed at the enhancement of teaching and learning. The factors Openness to Experience, Conscientiousness and Extroversion (in this specific order) were found to be advantageous for successful teaching and learning. Conscientiousness was found to predict final test results and procrastination (De Bruin 2000:108). The researcher is of the opinion that the increasing diversity of students in Higher Education (in SA) in recent years requires better and more scientific ways of conducting personality assessments, which might be useful, responsible and fair to students. McCrae and Costa (1987:81–90), as well as Taylor and De Bruin (2006:11-36), agree that students bring along a wide range of abilities, interests and backgrounds, based on culture, race, gender, and other aspects of diversity.

The subsequent section will describe the five components of the Five Factor Model of personality and the model's usefulness in detail.

#### *4.3.4.1 Extroversion*

Extroversion seems to be one trait common to all personality trait theories (Taylor & De Bruin 2006:9). This concept has its roots in Jungian psychology. According to Eysenck (1970:43), extroversion refers to the degree to which an individual enjoys company. The extrovert likes excitement, stimulation and has a cheerful disposition (Eysenck 1970:43). Eysenck (1970:44) proposes that 'Extroversion-Introversion' is one of the three dominant bipolar personality traits. Extroversion is sub-divided into five facets by Taylor and De Bruin (2006:9):

i) Ascendance is the degree to which individuals enjoy entertaining and leading or dominating large groups. It reflects differences in assertiveness and social visibility. The essential elements of Ascendance include Exhibitionism (the degree to which individuals are entertaining and dramatic) and Dominance (the degree to which individuals enjoy controlling/influencing others).
ii) Liveliness resembles the degree to which an individual are bubbly, lively and energetic.
iii) Positive affectivity is an inclination to feel happy, cheerful and optimistic about the future (joy) and to be easily excited and enthusiastic over life events.
iv) Gregariousness is an indication of preferring frequent social interaction and being surrounded by others, as opposed to being alone.
v) Excitement seeking represents the need for adventure and adrenaline-pumping experiences. Individuals find stimulation in bright colors, noisy places and other intense sensations.

According to Taylor and De Bruin (2006:9), "Individuals who score high in Extroversion are generally those who enjoy being around people, especially large gatherings, and tend to be assertive, active and talkative." According to these researchers, extroverts thrive on stimulation and excitement. They act cheerfully and optimistically. Low-scoring individuals (introverts) prefer their own company, are reserved, feel independent and prefer to perform at an even pace.

#### *4.3.4.2 Neuroticism*

The Oxford Advanced Learner's Dictionary (2010:991) links neuroticism to synonyms such as "Anxious, unstable, disturbed, confused, irrational, disordered, maladjusted, nervous and obsessive." According to De Raad (1992:19), neuroticism refers to the emotional stability of individuals, and indicates a tendency to experience negative effects in response to the environment. Taylor and De Bruin (2006:11) sub-divide neuroticism into four facets, namely:

i) Affective instability represents the tendency to become easily upset, have feelings of anger or bitterness and to be emotionally volatile.
ii) Depression is a tendency to experience guilt, sadness and hopelessness, and to feel discouraged and rejected.

iii) Anxiety represents a tendency to experience nervousness, apprehensiveness, tension and worry.

iv) Self-consciousness is the degree to which individuals are sensitive to criticism, and includes frequent feelings of shame and embarrassment.

De Raad (1992:18) indicates that this trait has a negative influence on achievement at Higher Education level. The depressed character has a tendency to neuroticism, which inhibits academic success. However, research has indicated (De Bruin 2000:111) that individuals with high conscientiousness levels may be motivated by neurotic feelings, as they are already conscientious in their work. Students with low neuroticism are confident in terms of their preparation for examinations. De Bruin (2000:111) reports that such students spend more time to engage with their studies. On the other hand, there is a positive correlation of neuroticism with procrastination (Taylor & De Bruin 2006:11).

#### *4.3.4.3 Conscientiousness*

Conscientiousness is the degree of effectiveness and efficiency with which individuals plan, organise and carry out tasks. Taylor and De Bruin (2006:11), the authors of the Basic Traits Inventory (BTI), define conscientiousness as: "…the self-discipline required in planning, organising, and carrying out of tasks". Individuals with high scores in conscientiousness are focused, strong-willed, and determined. They also tend to be dependable, hardworking, achievement-orientated, and persevering.

In view of the above, Taylor and De Bruin (2006:11) state that low scorers on the BTI tend to be more relaxed in working towards their goals, and may tend to be more hedonistic, distractible and impulsive than high scorers. Individuals who score low on the 'order' facet of conscientiousness prefer less organised environments and dislike routine. When studying in the Sciences (where theorems and laws guide deduction and analysis of problem-solving), these traits are all important. According to Taylor and De Bruin (2006:11-19), conscientiousness exhibits five facets, namely:

i) Effort entails a sense of rationality and efficacy in tasks and can also be described as industriousness, manifesting as a hardworking, diligent, resourceful, confident and ambitious nature.

ii) Self-discipline or self-control represents a tendency to begin with tasks immediately and carries these out to completion. It also indicates an ability to motivate oneself to complete unpleasant tasks.

iii) Dutifulness indicates an individual's adherence to moral precepts, as well as duty, indicative of being of service to others, participating in community projects, and being reliable and dependable.

iv) Order is a tendency of neatness and tidiness, manifesting an individual's organisational ability. It is also indicative of a methodical individual, who plans and organises tasks and activities.

v) Prudence refers to the tendency to think things through carefully, checking facts and practising good common sense, as opposed to being impulsive and making rash decisions. Deliberation can be related to purposeful planning and careful decision-making, prior to acting.

McCrae and Costa (1991:372) found that this personality factor proves to be a successful predictor of students' final course marks. It also serves as an objective measure of possible test achievement. Conscientiousness indicates whether students will engage with effort and avoid procrastination with tasks in time; all appropriate traits for Science studies.

#### *4.3.4.4 Openness to Experience*

The concept of Openness to Experience refers to a willingness to experience new or different things and a curiosity about the self and the world. Taylor and De Bruin (2006:12) sub-divide Openness to Experience into five facets:

i) Aesthetics refer to a tendency to have an appreciation for art, poetry and beauty, without talent in art being a necessity.

ii) Values refer to the degree to which an individual are willing to re-examine social, political and religious values, as opposed to accepting authority and honouring tradition.

iii) Actions refer to the degree to which individuals are prepared to attempt new and different activities.

iv) Ideas relate to an individual's curiosity, whether he/she enjoys considering new or unconventional ideas. Such individuals relish philosophy and brainteasers.

v) Imagination refers to being creative. Enjoying fantasies manifests a vivid imagination.

Taylor and De Bruin (2006:12) indicates that Openness to Experience also describes an individual's tendency to be imaginative, intellectually curious and open to attempt new things. Such individuals are likely to manifest in the workplace as those who accept workplace changes and transitions, create new ideas and remain open to alternatives. Taylor and De Bruin (2006:12) view individuals with a high degree of Openness to Experience as highly tolerant of ambiguity and uncertainty, making them ideal employees in a fast-changing work environment.

They lead experientially rich lives and seek out novel ideas. Taylor and De Bruin (2006:11) are of the opinion that individuals with low Openness to Experience seem to manifest a conventional and conservative behaviour. They exhibit a narrow scope and intensity of interest and are comfortable with traditional values and ways of thinking.

#### *4.3.4.5 Agreeableness*

Agreeableness refers to the degree to which individuals are able to get along with other people (Taylor & De Bruin 2006:13), as well as having compassion for others. These researchers provide the following definition of agreeableness: "Individuals high in agreeableness tend to be sympathetic towards others, straightforward, selfless, are eager to help, and believe that others will be as helpful in return. Individuals who score low on agreeableness tend to be sceptical, manipulative, competitive, and self-centred. In other words, they look after their own interests".

Agreeableness is sub-divided into five facets by Taylor and De Bruin (2006:13):

i) Modesty represents the degree to which individuals are humble and self-effacing.

ii) Prosocial tendency reflects the degree to which individuals show a propensity to be kind, generous, helpful and considerate.

iii) Tender-mindedness is a tendency to show sympathy and concern for others.

iv) Straightforwardness represents a tendency to be frank and sincere, as opposed to bring deceitful and manipulative.

v) Compliance refers to the degree to which individuals defer to others, inhibit aggression and are able to 'forgive and forget'.

#### *4.3.4.6 Usefulness of the Five Factor Model*

The usefulness of the Five Factor Model is reflected by the fact that the Five Factor structure provides a framework by means of which to understand relations among the various traits. De Bruin (2000:145) found that the Five Factor Model also offers a common, theoretical language to use when studying personality and related concepts. The model became popular in recent years, due to its comprehensiveness and replication value across other well known models (De Bruin 2000:145). In criticising the Five Factor Model, Larsen and Buss (2002:145), warn that scores on individual traits should not be viewed in isolation or out of context, as the whole is often greater than the sum of its parts. In summary, while there is general consensus on the existence of five personality factors, there is limited agreement on the terms of use. For the purpose of this study, the researcher uses the labels, as proposed by McCrae and Costa (1987:81-90) as stated below and presented as a hierarchy. The hierarchical representation of the Five Factor Model and BTI can be viewed in Figure 4.4. The facets of each of the five traits are listed underneath in separate columns, as explained in Sections 4.3.4.1 - 4.3.4.5.

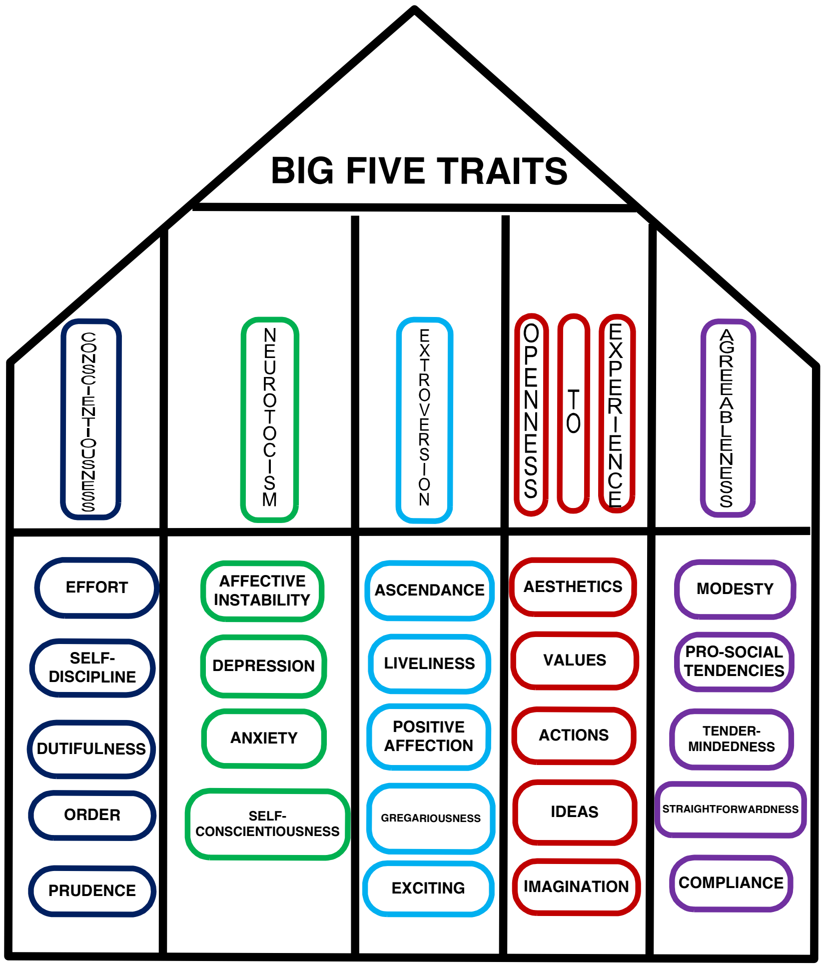


***Figure 4.4*** **The hierarchy of the Big Five personality traits**
(Adapted from Taylor & De Bruin 2006:11)

In a study of personality scales by Taylor and De Bruin (2006:13) a longitudinal investigation over seven years, the following findings on the Five Factors were obtained:

- Extraversion was only indicative of early academic achievement and therefore insignificant in predicting academic success in later years.
- Openness to Experience (intellectual curiosity and aesthetics), agreeableness (trust, straightforwardness and tender-mindedness) and conscientiousness (self-discipline, striving for achievement and competence) increased in importance over the seven years.
- Personality variables have modest predictive validity in comparison to cognitive abilities.

Various studies (De Raad 1992:25) examined the cross-cultural applicability of the Five Factor Model. This model was used in Estonian and Finnish populations, as well as by the Dutch and

Germans. Accordingly, it seems that personality-related concepts are similar across language groups. McCrae and Costa (1991:368) state that personality traits may be universal, as they demonstrate a similar structure to the Five Factor Model in various cultures.

Although numerous international studies have been conducted on the cross-cultural application of the Five Factor Model, only limited research on examining the model's use was conducted in the SA context. Studies by Heuchert, Parker, Stumpf and Myburgh (2000:113) in this regard appear to be contradictory. For example, Heuchert *et al.* (2000:116) established that the Five Factor Model existed for both White and Black South African students. Taylor (2004:148) and Taylor and De Bruin (2006:38) found that Big Five traits are evident in Afrikaans, English, Nguni and Sotho speakers. Heaven and Pretorius (1998:665) propose that the natural language approach in describing personality traits is inappropriate for the South African population, and that a South African-deduced personality measure was required. The Basic Traits Inventory (BTI) (Taylor & De Bruin 2006), as used for the purpose of this study, may be able to fulfil this requirement. The BTI was designed to assess the Big Five factors of personality in the unique South African population (Taylor & De Bruin 2006).

#### 4.3.5 The Basic Traits Inventory

The BTI personality-elements are similar to the Five Factor Model and include the following: Conscientiousness, Neuroticism, Extroversion, Openness to Experience, and Agreeableness (as stated above). Taylor (2008:v) provides evidence of the transportability of several international personality tests and theories. However, the Five Factor Model received empirical support in the South African context. In research conducted by Huysamen (2001a:141), it was found that Black students perceive psycho-educational testing to be Eurocentric in nature and instruments of exclusion. Such feelings of discontent must therefore be managed very carefully if institutions expect students to participate in any testing (e.g. National Benchmark Test).

A BTI and a BTI-SF (shortened version of the BTI) are available, with both measuring the Big Five personality traits. The BTI consists of 193 items, and the BTI-SF of 60 items, rated on a five-point Likert type scale that range from "strongly disagree" to "strongly agree". They are both paper-and-pencil tests, whereby respondents are required to complete a questionnaire by means of self-reported answers (Taylor & De Bruin 2006:12). The standardisation sample for the BTI consisted of 5 352 respondents representing the following: police applicants and trainees (62.2%), undergraduate psychology students (17.8%), medical aid call centre employees (2.7%) and Masters of Business Administration (MBA) students (3.2%). The sample represented the South African population accurately, with the ethnic status of the sample being Black (66.3%), White (14.8%), Coloured (3.4%), Asian (2.6%) and unspecified (13.0%).

By means of factor analyses the Big Five factors emerged across the various cultural groups in South Africa. The results indicated that particular personality factors were found in both the Black and White population groups (Taylor 2004:45; Taylor 2008:103; Taylor & De Bruin 2006:13-15). All five factors emerged clearly in both population groups and are therefore applicable in the South African context. The reliability coefficients for the five traits varied between 0.85 and 0.92 for Black respondents and between 0.89 and 0.95 for White respondents, as indicated in Figure 4.5.

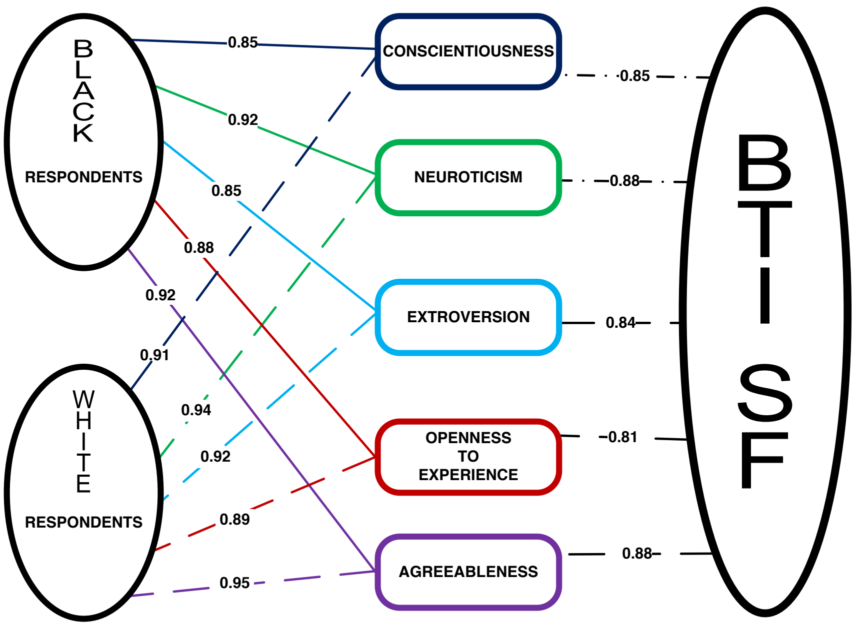


***Figure 4.5*** **The Alpha Reliability Coefficients for the Basic Traits Inventory correlation**
(Adapted from Taylor & De Bruin 2006:16, Taylor 2008: 103-104)

The correlation for the BTI-SF is between 0.81 and 0.88 in comparison to the total BTI measurements of between 0.87 and 0.93, indicating acceptance of the BTI as a measuring instrument in the South African context.

This investigation recognises variations in personality contributing to individual differences. Personality type, context of the environment and the specific situation all impact on behaviour and ultimately on achievement. Where studies in personality are conducted at an individual level, the study of cultural dimensions is conducted at cultural (or group) level. This is an important distinction when personality traits are used in conjunction with cultural dimensions, such as individualism and collectivism (Taylor 2008:21). The modern approach is to integrate personality studies across cultures into a holistic overarching investigation applicable in all societies.

#### *4.3.5.1 A multi-cultural approach to personality*

The so-called Big Five personality factors received worldwide support for their cross-cultural applicability. Sub-Saharan Africa studies have been limited to South African research conducted by Heuchert *et al.* (2000) and Taylor (2004), among others. Taylor (2004:64) examined the construct comparability of the Big Five in Black and White South African employees, using the Neuroticism Extroversion Openness-Personality Inventory-Revised (NEO-PI-R). Her findings indicated that the Five Factor structure is useful for the White sample, but not the Black sample. This can possibly be attributed to use of language, as many respondents indicated difficulty in understanding the terminology. The terminology is generally problematic, with foreign personality measures being used in South Africa. However, BTI results, prove to be useful across ethnic groups and provide the rationale for its utilisation in this research. The terminology can also be simplified when showing the opposites of each trait (Figure 4.6 below). The five traits are represented by the acronym OCEAN, and are presented on a bi-polar scale.

This presentation of the two extremities of the scales, represent the way individuals react and manifest underlying preferences. Under no circumstances can the instrument be used with only one isolated scale to determine successful student profile.

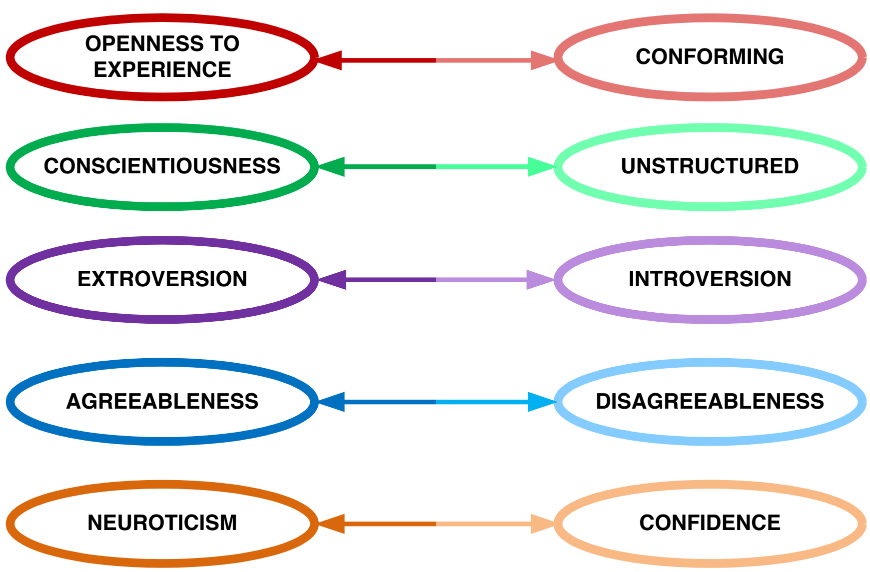


***Figure 4.6*** **The Big Five personality traits continuum**
(Adapted from McCrae & Costa 1987)

The insight into the presence of dominant traits of students will complement decisions to be made on placement. This investigation includes personality traits, in order to probe if student profiles provide additional information regarding academic success. If it were possible to make proposals about preferable traits for first-year student performance, students could most probably be placed in appropriate academic programmes. For university studies in Science the following scores in traits may provide useful information:

- High scores in Openness to Experience are related to actions such as creative thinking, taking risks and solving problems.
- High scores in Conscientiousness manifest in reliability and efficiency, perseverance and dutifulness, keenness to achieve goals, an organised and structured approach to work and studies, and commitment.
- High scores in Agreeableness are visible in tolerance and patience towards others.
- Low scores in Extroversion will indicate the ability to focus on a prolonged task.
- Low scores in Neuroticism manifest in a relaxing under pressure, high self-esteem, coping with the unexpected, and optimism.

The above indicates that higher scores in Openness to Experience, Conscientiousness and Agreeableness are advantageous for academic achievement when coupled to low scores in Extroversion and Neuroticism.

### 4.3.6 Personality traits and academic performance

The relation between non-cognitive and cognitive individual differences and the underlying acquisition of knowledge was researched by Chamorro-Premuzic and Furnham (2003:238-250). According to this research, personality traits play an important role in the acquisition and development of knowledge and direct individual choices and level of persistence.

Academic achievement is associated positively with Openness to Experience. Chamorro-Premuzic and Furnham (2003:237) relate this to Intellect. Extroversion, as well as Neuroticism, varies with regard to academic performance. Traditionally, introverts exhibit an ability to consolidate learning, are less distractible than extroverts and have good study habits (Chamorro-Premuzic & Furnham 2003:238). Studies prove that extroverts "…under-perform in academic settings because of their distractibility, sociability and impulsiveness." The narrow traits, activity and gregariousness, are both significantly negatively correlated with examination achievement, thus strengthening the previous statement that introverts ('nerds') are more inclined to achieve academically (McKenzie, Gow & Schweitzer 2004:100 &109).

From the above, the following conclusions are postulated by the researcher: The negative correlation between Neuroticism and academic success can be explained by the fact that individuals with high Neuroticism levels experience increased stress and anxiety levels when being assessed. On the other hand, Neuroticism can also serve as a positive predictor, as anxiety may motivate highly intelligent students. As a specific or narrow trait of Neuroticism, anxiety will impede the achievement in Mathematics indefinitely. Anxious individuals lack confidence in their abilities which will impede their performance.

Costa and McCrae (1992:370), Chamorro-Premuzic and Furnham (2003:239) all indicate that the most consistent trait associated with academic success is Conscientiousness. The aforementioned studies confirm the relation between general mental ability and Conscientiousness. The two narrow traits of Conscientiousness, namely dutifulness and effort (also known as striving for achievement), correlate significantly with examination results, while self-discipline contributes significantly to academic achievement.

Students with the required scholastic ability will achieve success faster and with less frustration. “Those who are not as gifted can compensate with perseverance and tenacity” (Schwartz 2006:51). According to Schwartz, there are three requirements to encourage successful Mathematics learning:

- The student must bring perseverance and fearlessness to class.
- The lecturer contributes to the environment with compassion and knowledge, thereby encouraging risk-taking.
- They (the lecturer and the student) should commence at the appropriate level of engagement with course content (cf. Section 4.6).

In the opinion of the researcher, perseverance can be described as the ability to continue despite obstacles, “…stay with problems longer…” by attending classes regularly and making use of tutoring. Fearlessness indicates not being afraid to make mistakes or ask questions. Lecturers should assist students to read the text (cf. Section 3.3.2.2). Mathematics is often regarded as only calculations – resulting in an inability to absorb important and guiding information. Mathematicians should always consider the fact that very few students in their undergraduate classes will follow in their footsteps and do doctorates in Mathematics. Nevertheless, students in Science, Engineering and Medicine require critical and analytical thinking skills that Mathematics provides so elegantly.

In view of the above there are various attributes to boost success, such as stability, ability, effort, skill and talent (as indicated by Linnenbrink and Pintrich 2002:317). Stability, ability and effort are related strongly to personality traits and cannot be isolated from talent and skill (related to general mental ability or scholastic ability). Students with the high scholastic ability and coherent personalities still require motivation, a positive attitude and self-efficacy to be academically successful.

## 4.4 MOTIVATION

In this section, the second non-cognitive factor associated with academic achievement namely motivation, will be discussed, as indicated in the diagram below (Figure 4.7). Except for general mental ability, authors such as Eiselen and Geyser (2003:124), Linnenbrink and Pintrich (2002:313) and Wentzel and Wigfield (1998:16) allege that motivation is the second largest contributor to academic success. It indicates motion or movement (from the Latin movéré). Motivated individuals move in the same direction as the purpose of the action. The researcher is of the opinion that students can be motivated in multiple ways, that motivation levels are unstable and that such levels vary in specific situations, contexts and domains. For example, students may be highly motivated in languages but not in Mathematics. They might even be motivated in a specific theme in Physics (e.g. electricity) but not in another (e.g. mechanics). Motivation can be divided into extrinsic or intrinsic motivation, and each of these can manifest as social or achievement motivation. It can be directed by external or internal forces and will be classified accordingly. Biggs and Tang (2007:31) argue that by involving students, so that they can engage in the task, serves as motivation for learning. Making the work or the learning important to learners at school or students at university will make them value their own input.

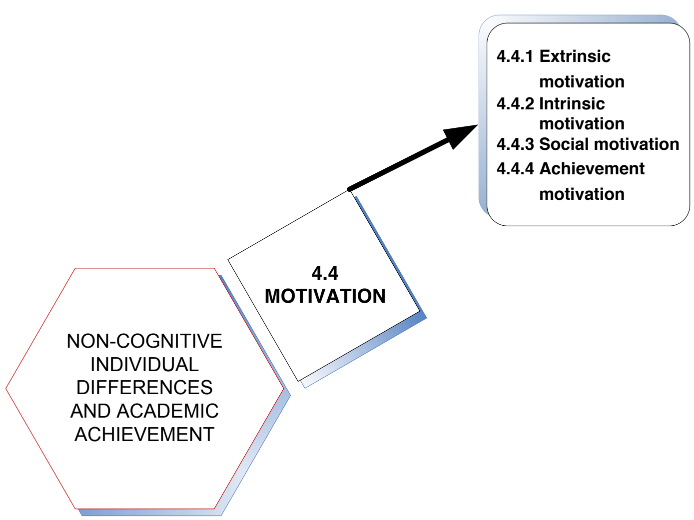


***Figure 4.7*** **Motivation and academic achievement**

### 4.4.1 Extrinsic motivation

Extrinsic motivation results from external factors, such as examination and parental pressure or financial gain. Deci and Ryan in Aronson (2002:65) believe that at school level, young learners can easily be motivated by rewards and praise. The majority of students at university level who only "…perform the task because of the value or importance they attach to the outcome…" require extrinsic motivation (Biggs & Tang 2007:35). They are not self-directed learners (De Bruin 2000:82) and will experience problems in Higher Education. Extrinsic motivation is therefore often linked to a surface approach to learning (to be discussed in Section 4.6). Schwartz (2006:52) adds that such students usually expect maximum results from minimum effort and time inputs. This approach therefore results in them focusing on the consequences and not the task at hand. Biggs and Tang (2007:35) explain that this may lead to anxiety, anger and shame, which will impede academic achievement.

### 4.4.2 Intrinsic motivation

Intrinsic motivation, such as a personal drive for performance or thirst for knowledge, is embedded within individuals. Research conducted by Deci and Ryan (2002:75) proved that students who were intrinsically motivated studied at a conceptual level and applied a deep learning approach to learning (cf. Section 4.6). According to Linnenbrink and Pintrich (2002:318), one of the defining features of intrinsic motivation, is "high personal interest" in the task. Inherent tendencies that manifest in individual behaviour include a propensity to take on challenges, to learn and to explore (as reiterated by Deci and Ryan 2002:64).

Intrinsically motivated or self-motivated students perform and engage in an activity out of spontaneous interest or desire, not expecting any reward. Biggs and Tang (2007:36), among others, state that such students will study Mathematics purely for the intellectual pleasure and challenge, resulting academic excellence. Anthony (2000:5) and Pickworth (2001:140) share the notion that self-motivated students and lecturers achieve success. Students with an "achieving approach" engage with learning, exhibit potential to understand and attempt to achieve good results. Such students experience an ego-boost from the recognition of their prior achievements and are highly adjustable. These attributes are vital to becoming a successful student at university.

Strategies adopted by self-motivated students (as listed by Pickworth 2001:140) include that they read widely, seek inter-relation between existing and new knowledge, and integrate meaning with their personal experience and interest. Self-motivated students are able to manage time efficiently, plan ahead, and have an organised working space. The aforementioned actions taken by self-motivated students imply that deep learning is taking place. Lecturers can actively enhance achievement in students by expecting them to achieve at high levels. This well-known “Pygmalion effect” has been proven to increase student motivation levels. In the musical “My Fair Lady”, the character, Eliza Doolittle manifests this effect with her enhanced performance. “It is not the way she behaves but the way she is treated…” according to Doctor Higgins, her mentor. Rosenthal in Aronson (2002:29) predicts that if lecturers believe, that students can be successful, they will act accordingly.

External or internal motivation manifests in social and academic environments which will be discussed subsequently.

### 4.4.3 Social motivation

Biggs and Tang (2007:35) postulate that many students study hard to please those who have a particular opinion of them. Being successful and performing well will become important for students if a family or group of friends value their performance. Being like the group, admiring role models and “learning to become” a Scientist (as stated by Pretorius & Jacobs 2008) inspires students to achieve.

### 4.4.4 Achievement motivation

The enhancement of ego by achieving is when students feel good about achieving. Biggs and Tang (2007:35) claim that students with achievement motivation often achieve well, but also that the drive to achieve often alienates them. Competition with fellow class members impacts on relationships and trust and might even result in anxiety and loneliness.

Given the above, achievement in the academic environment will depend on achievement motivation which in turn, should enhance academic success. Motivated individuals direct actions toward the aim and if self-motivated, the achievement will inspire working toward another achievement.

## 4.5 INTEREST

In this section, the third non-cognitive factor associated with academic achievement, namely interest, will be discussed, as indicated in the diagram below (Figure 4.8). Interested students perform well and become successful in their academic studies.

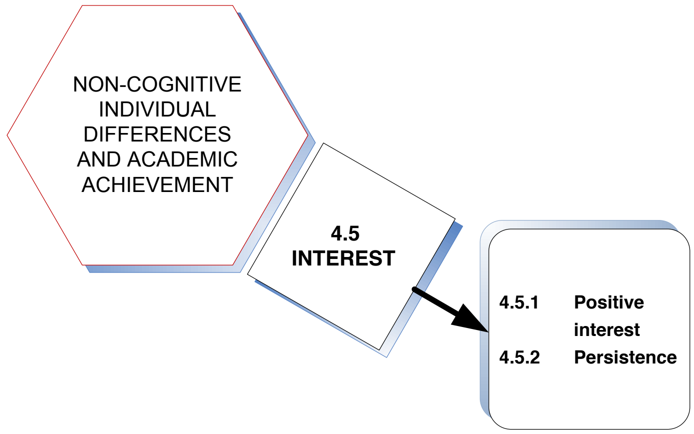


***Figure 4.8*** **Interest and academic achievement**

### 4.5.1 Positive interest

Although lay people may think interest and motivation are similar, Linnenbrink and Pintrich (2002:318) explain that interest can also be multi-dimensional. Murphy and Davidshofer (1998:36) are of the opinion that individuals usually like areas where they perform well or experiences that make them feel good. Whereas general mental ability predicts achievement and efficiency, interest will be able to predict persistence and satisfaction.

Linnenbrink and Pintrich (2002:318) define interest as "…an interaction between the individual with his or her environment…", whereas in Murphy and Davidshofer's opinion, (1998:35) interest is "…a learned affective response to an activity or object…" A distinction is also made between personal or individual interest and situational interest. Personal interest reflects the interest an individual has in a particular domain or theme and is mainly stable. In contrast, situational interest is determined by a specific context and is usually short-term. Both types of interest can influence academic achievement and are related to persistence and increased attention.

The successful student will be equipped with specific skills, which in turn, will provide graduates with an opportunity for a positive future. According to Shireman (2009:54), graduates are active participants in the economy of their country and key role players in their families (cf. responsiveness Section 2.3). General liking or interest in the field of study can determine achievement in specific disciplines. Challenging content such as Mathematics and Science are perceived to be more achievable if students are interested in these subjects. According to Allen and Robbins (2007:62), the choice of a field congruent with students' skills and interests is likely to result in successful studies.

Positive interest is said to motivate students to study and can also inform choice of study field (Murphy & Davidshofer 1998:36). This motivation will provide the ‘energy’ or ‘catalyst’ to inspire students to perform academically. Interested students are motivated, and work hard. According to Kahn and Nauta (2001:641), interest also cultivates good study habits and methods. Such students are self-directed learners and achieve academically. Allen and Robbins (2007:63) add to this by indicating “…that students who choose majors consonant with their interests are more likely to persist in their chosen major.” An interested student is also inclined to persist with academic challenges in general (Murphy & Davidshofer 1998:36).

According to Kersop (2004:59) and De Bruin (2000:24) the interests of individuals usually manifest in their personalities; such interests will ensure that students are motivated and have a good chance to be academically successful. The determination of interest is conducted with different inventories and can be deduced from Holland’s personality typification (cf. Section 4.3.2). For the purpose of placement of students in Science programmes, a determination of the Science interest level of prospective students will therefore be useful. Murphy and Davidshofer (1998:39) express the view that interested students will feel positive and be able to achieve challenging learning content such as Mathematics and Science. In addition, Kahn and Nauta (2001:641) are of the opinion that the various disciplines taught in schools and in Higher Education are different, and similar to every workplace variable, do not have a straightforward relation with personality types.

Students with an interest in their studies should achieve academically as they have an inner-drive to know more and they feel positive. However, students also need to persist especially with difficult content such as Mathematics and Science.

### 4.5.2 Persistence

Lufi, Parish-Plass and Cohen (2003:1), as well as Kahn and Nauta (2001:641), found a significant correlation between persistence and achievement grades during their research. Persistence is predicted by student background and is one of the strongest predictors of first-year achievement. It results from a suitable match between student characteristics and the institution. In addition to interest being an indicator of success, it may also be a determinant of satisfaction with choice and therefore persistence in that choice. Some indication of persistence is shown by Scott (2007:2), indicating that only 30% of South African students graduate in five years, and only 51% of students in the USA complete their qualifications in the minimum timeframe (Allen and Robbins 2007:63).

Students will flourish in an academic environment that is suitable to their personality type (cf. Holland in Section 4.3.2) or personality trait (cf. Big Five in Section 4.3.4). Allen and Robbins (2007:76) support this notion and propose that to determine students' personality profiles in conjunction with interests and persistence will provide valuable information about their placement in an appropriate academic programme. Lowe and Cook (2003:53) also indicate that a lack of interest in academic work can be associated with disengagement with academic and social activities required at university level.

The importance of motivation and interest for academic success are outlined above. The influence of persistence as a underlying attribute will have a major role to play in the acquiring of difficult and complex content embedded in Science disciplines. These and other factors culminate in the teaching and learning that will be discussed in the next section.

## 4.6 TEACHING AND LEARNING

In this section, the fourth non-cognitive factor associated with academic achievement, namely teaching and learning will be discussed, as indicated in the diagram below (Figure 4.8). Academic success depends on the factors discussed above, as well as study habits and students' learning strategies. Lecturers and teaching strategies, as well as the learning environment, also contribute to a successful learning experience for students. The extent to which teaching strategies correlate with academic achievement will determine successful learning.

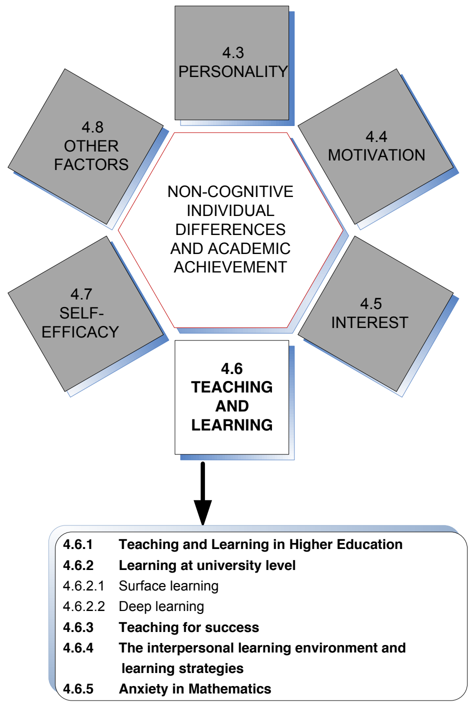


***Figure 4.9*** **Teaching and learning and academic achievement**

Teaching and assessment at school level tend to develop study skills and learning strategies that are worlds apart from the independent style required for Higher Education. Lowe and Cook (2003:53) found that even excellent students from school feel under-prepared to cope with learning styles expected in a formal university lecture. The required study skills (note taking, additional reading, research, time management, posing questions, functioning in large groups, team work and computer literacy) for Higher Education are different to what functioned well at high school level. Many lecturers make the misguided assumption that Higher Education skills and a culture of learning had been established at school and will be cultivated further within the structure of lectures and teaching content. The OBE approach complicates adjustment from school with first-year students used to a different style of teaching and learning at school.

### 4.6.1 Teaching and learning in Higher Education

South Africa adopted an Outcomes-Based Education (OBE) approach in 1997, where learning outcomes are formulated as targets. The targets should be met by all learners, who should all experience some degree of success. According to Gravett (2004:90-110), Outcomes-Based Education was proposed by William Spady, as a means to address individualised programmes for disadvantaged learners. Learning outcomes are prescribed to measure what and how well learners and students are able to achieve in an area where they had shown inability before teaching and learning took place. Educationists, politicians and psychologists have many opinions on the implementation and results of the Outcomes-Based Education-system. This investigation acknowledges the various views on Outcomes-Based Education, with cognisance of the fact that there is an increased emphasis on assessment (as also mentioned by Biggs and Tang 2007:7).

In Outcomes-Based Education, outcome statements indicate what students should be able to do. Constructive alignment is to systematically align "…teaching/learning activities and the assessment tasks to the intended learning outcomes, according to the learning activities required in the outcomes" (Biggs and Tang 2007:7). The researchers reiterate "…good teachers have always had some idea of that – that is one reason why they are good teachers." According to Biggs and Tang (2007:7) and Gravett (2004:94), to mention only these researchers, one advantage of Outcomes-Based Education, is the fact that it aligns teaching, learning and assessment.

Students enter the university lectures at different levels of competence, knowledge, interest and maturity (Biggs and Tang 2007:11) and although they attend similar lectures they have different dispositions. Teaching methods should stimulate the degree of learning and narrow the gap between students, in order for them to reach the point where they graduate. Some of the students may have little real motivation and very little background knowledge. These students seldom engage in questions and puts in the minimum effort in order to pass and are usually passive during lectures and attempts to remember the bare minimum to perform. Students with such a low motivation start at a very low level of engagement (resembling a surface approach to learning) according to Smythe and Halonen (2005).

On the other hand, other students are academically committed, bright and interested in the course. Such students usually have a clear career path and regard the content as being important. They come to lectures prepared, ask questions and constructs knowledge while in class. These committed students teach themselves by means of constant reflection on what and why they are learning. Furthermore, they relate and apply content to a well-constructed knowledge base. In fact, they do not require a lecturer to facilitate most of the learning. These students are relating, applying and theorising, using a 'deep' approach to learning (with reference to higher order engagement of Bloom's revised taxonomy (Smythe & Halonen 2005).

Biggs and Tang (2007:11) believe that good teaching can inspire most students to achieve if they make use of lecturer support, guidance and engage in learning activities that come spontaneously. This important indicator should be included in the framework for placement. In the current decade, teaching in the university environment is more challenging than ever before. In the international Higher Education sector, concerns about student achievement are discussed continuously (cf. Section 2.3). According to Biggs and Tang (2007:17–19), there are different opinions about the reasons why students enter the system.

The "blame-the-student" theory claims that students do not learn due to a lack of ability and motivation, or even ethnicity and stereotyping. This theory blames poor achievement on factors other than teaching (such as background and schools). Blaming-the-student has been referred to as "Academic Darwinism", indicating that such students should never have been enrolled, and that only those surviving the first semester would be able to graduate.

Lecturers sometimes over-compensate and do all they can (using a variety of methods and taking all the responsibility) in a teacher-centered approach. If successful learning does not take place with all this teaching effort, the blame shifts to the lecturer. Biggs and Tang (2007:18) warn that care should be taken that the focus does not become the skill of lecturing, but rather its effect on student learning. The above discussion sheds light on the student activity and responsibility. According to Biggs and Tang (2007:19) teaching, supports learning. If learning does not take place, all the electronic devices and techniques for entertaining students become irrelevant. The important question that university lecturers should be able to answer and explore is: "How do students in my course learn?" Careful selection of lecturers can complement successful placement of students.

### 4.6.2 Learning at university level

Evidence suggests that the first year of Higher Education is challenging. According to Stone (2000:58), the first year "…represents a difficult transition for many students, during which they are at risk emotionally and psychologically." While the importance of various 'human dimensions' (e.g. perceptual activities, social processes and environment) are recognised, Bitzer (2005:178) urges educators to pay attention to the non-cognitive as well as the cognitive of student requirements in order to maximise learning opportunities.

Student learning has been researched since the 1970's, when Marton and Säljö studied the surface and deep approaches to learning. Biggs and Tang (2007:20), as well as Gravett

(2004:27), emphasise that in developing theories of learning, the preparation of students requires knowledge of the discipline, the student and the learning approach. Knowing is much more than being assessed and passing grades. Gravett (2004:27) adds that knowing is much more than graduating and the delivery of a product; knowing is a process and takes time. Knowing, as a result of teaching or effective change in learning, is neatly phrased by Biggs and Tang (2007:20) as "…the way we see the world."

Researchers such as Biggs and Tang (2007:20) and Gravett (2004:28) agree that education can bring about conceptual change, which is not possible if information is merely transmitted.

#### *4.6.2.1 Surface learning*

Some students are merely focusing on facts and might even pass (depending on the assessment). According to Biggs and Tang (2007:22), remembering a list of disjointed facts (cf. revised Bloom Figure 3.5), involves actions such as verbatim recall and listing independent items, requiring a low level of engagement with learning, referred to as a surface approach. This approach will remove the task. Gravett (2004:93) lists factors that will encourage students to adopt a surface approach, namely:

- Teaching large quantities of content and overloading students with a demanding curriculum.
- Emphasising coverage at the expense of depth.
- Frequently assessing for credits, and creating low expectations.
- Demanding recall of content and independent facts, when assessing.
- Placing a low premium on adequate feedback on assessment and progress.

Rote learning and memorisation methods that proved successful at school level will not be sufficient to pass at Higher Education level as it results in a surface approach to learning. Surface learning tends to make students feel anxious and uncertain. Learning directed towards moving from a part (particular) to the whole (general), known as the inductive method (cf. Section 3.3.2.3) is also known as the behaviorist approach. Eiselen (2006:80) indicates that the behaviorist approach contributes to success at school level but that university success requires a constructivist approach that facilitates critical thinking. Analytical and critical thinking skills develop from problem-solving, and when students take responsibility for their own learning. Self-directed learning, as researched by De Bruin (2000:145), serves as a good predictor of academic achievement and will ensure that deep learning takes place.

#### *4.6.2.2 Deep learning*

There are also those students manifesting the characteristics of self-directedness. Their learning can be described as active, constructive and self-directed processes. De Bruin (2000:147) explains the behavior of these students accumulating internal knowledge representations that are personal interpretations of their learning experiences. The learning approach of students are learning to become scientists, to become engineers, and therefore "learning to be" (according to Bruner, cited in Brown and Duguid 2000:12). This approach represents a deep learning approach where students attempt to construct meaning, or as Biggs and Tang (2007:24-25) state, to get the bigger picture. Focusing on the underlying meaning (below the surface) requires a sound foundation of relevant prior knowledge, and students being positive and interested. Gravett (2004:25) lists factors that will encourage students to adopt a deep learning approach, namely:

- Teaching by focusing on main ideas and relationships in the knowledge domain.
- Emphasising depth rather than coverage.
- Teaching by building on students' foundational knowledge and confronting misconceptions.
- Engaging students, and using formative practices to support learning.
- Assessing for understanding and application, and providing constructive feedback on assessment and progress.

Mathematics and Science require problem-solving related to deep learning (cf. Section 3.4.2.1) and continuous practice. Eiselen (2006:82) and Maree and Crafford (2005:91) remark that students practise calculations and problems taught in class, in their textbooks, or required in tutorials. As soon as they are confronted with new or unfamiliar problems, they are unable to begin or recognise any familiar component. The whole cycle described in section 3.4.2.3 indicates that moving from the physical world (data, problems and events) to the idea world (idealising, deducing, inducing, understanding and solving the problem) becomes appropriate. Problem-solving skills are essential for success in Science studies. Bressaud in Kratz (1999:179) states that "Mathematics is not a spectator sport" and must be practised daily.

While most students generally lack time management skills, Grayson (1997:109) advises that it could be valuable to make attendance of group activities compulsory. Group activities such as lectures, tutorials, discussion groups and practical sessions are all conducive to deep learning. Freedom of movement and no obligation to attend lectures has been proven to correlate significantly with lack of success in the past (Grayson 1997:109 and Schroeder 2003:12).

Compulsory class attendance can assist students to develop the required self-discipline for successful Higher Education studies. Attendance, complemented by regular assessment and frequent, prompt feedback, can help students to develop the important skill of self-assessment (Grayson 1996:998).

Anthony (2000:5) interviewed successful students and found that they attended classes regularly, and took their own notes and were actively involved in lectures (Pascarella and Terezini 2000:63). They also exhibited an appropriate balance between social and academic life. The researcher is of the opinion that personal note-taking, writing down notes on what you do not know, and personal thoughts is “placing it in my memory”, while own handwriting creates ownership of content, which assists in embedding content faster.

Tysome in University World News (2007:1) explains that to provide a good ‘student experience’, lecturers must do their utmost to understand students. Although the new student generation is different, they are not less intellectual. This could implicate the adding of study skills into every module. Biggs and Tang (2007:22) caution lecturers to teach students present in their lectures. “It is not the good old days, where only the highly selected students sat in your classes.” Teach those that are there, not those you would have wanted!

### 4.6.3 Teaching for success

Lowe and Cook (2003:54) believe that many lecturers have a lack of understanding of the entry level and preparedness of new students. In most cases, lecturers at Higher Education level regard themselves primarily as content specialists – renowned researchers - and secondarily as teachers. In the researchers’ experience, many lecturers are reluctant to develop and change teaching strategies, as they often regard such a change as lowering of standards. After 30 years of teaching, the researcher has observed that lecturers are inclined to teach content (as they have done during the past decades), but seldomly take responsibility for students’ learning. Comments are made about students who do not cope and “…should never have been here…” – “blaming the student”, as mentioned before. This “Academic Darwinism” - where only a selected few will survive and be allowed into the domain of the discipline - must change if Science is to survive and grow.

Students mostly experience difficulty to adjust academically, socially and personally to a new Higher Education culture. Astin (2004:2) labels students’ attitude as “wait and see”, revealing uncertainty and a lack of confidence. By means of lecturers, institutions should assist students

"…to form realistic expectations of themselves and of their institutions" (Lowe & Cook 2003:55). Although lecturers teach, as well as facilitate or mediate the learning process, Grayson (1996:998) emphasises the overlap in interaction between lecturers and students that becomes evident in the joint responsibility for learning. Vermunt and Verloop (1999:265) propose that teaching and learning activities are "mirror images" and can be divided into three categories, namely i) processing, ii) affective and iii) regulatory functions. The processing function concerns presentation and clarification of content. The affective function aims at creating and maintaining a positive emotional climate for learners, while the regulatory function addresses the management of students' learning processes.

Bruner (as cited in Candy 1991:56) expresses his view of a learning process as follows: "A body of knowledge, enshrined in a university faculty and embodied in a series of authoritive volumes, is the result of much prior intellectual activity." To instruct in Science disciplines is not a matter of motivating students to commit results to memory. Rather, it is to teach students to participate in a process that enables the knowledge acquisition. Lecturers do not teach a module to produce living libraries on that content, but rather to motivate students to think mathematically or scientifically, for themselves. In this regard, Gravett (2004:95) states that knowing should be a process rather than a product.

Professor Jonathan Jansen, well known South African educationist, commented on teaching the "wrong stuff in a dangerous world. What is it that we teach, why and with what consequences? I have yet to meet students in my first-year class at the University of Pretoria who remember school teachers because of their skills at solving quadratic equations, their fluency in grammatical analysis, or their knowledge of the DNA double-helix structure. They remember single teachers who made a difference in their lives. They tell moving stories of individual teachers who taught them about community, about caring, about compassion and about change" (Jansen n.d.:1). The aforementioned implies that lecturers should facilitate learning by means of management strategies, as well as create an environment conducive to learning.

Brown and Duguid (1996:11-14) argue that knowledge is constantly changing and not static, and that learning "…involves active engagement in the process of that change." For the purpose of this study, 'humanising' is interpreted as actions taken (consciously or sub-consciously) to adjust teaching and structuring an appropriate learning environment to optimally meet students requirements, as primarily being humans, and secondarily being potential scientists (Pretorius & Jacobs 2008:3). "Humanising interventions" is a phrase used by

Grayson (1996:997) to describe direct human interaction, as well as any other management action taken to create an effective learning environment, such as scheduling review classes, additional assessment opportunities and adjustments to the pace of teaching to suit student requirements.

The teaching and learning process is affected by interpersonal relationships between students and lecturers. Broder in Stephenson (2001:57-66) recognises that students are more likely to accept responsibility for learning if the lecturing environment is open and based on mutual respect. Furthermore, efficient knowledge sharing can be facilitated by allowing students the time to become acquainted, so that trust (respect) can develop among them. Students and lecturers can engage during any contact time, such as lectures, tutorials and group meetings, where conditions of respect and trust prevail.

Evidence suggests that the transition between school and Higher Education proves to be a challenge; to the extent that students are at risk emotionally and psychologically (Stone 2000:68) (cf. Section 4.6.2). According to Grayson (1997:112) and Naidoo (1999:220) the university environment can utilise learning communities (study and mentor groups) to offer social and academic support. Learning is not only a personal but also a social activity (Tam 2000:9), and especially in Science laboratories, group work and cooperative learning are possible. Grayson (1997:113) agrees and concludes that a social context for learning can be a strong motivating factor.

According to Tam (2000:10), lecturers and students are active participants in the learning process. Through inspired teaching, lecturers can change the thinking, attitude, disposition and behaviour of students positively (Manning in Stephenson 2001:133-140). They can "guide pupils in their quest for knowledge" (Barnard 1997:80) and in the process, also teach values and morals, thus living the discipline. Leibowitz, Van Schalkwyk, Van der Merwe, Herman and Young (2009: 255-269) conducted research on first-year lecturers and listed attributes of good teachers (cf. Section 4.6.2.2). In addition, Chickering and Gamson (1999:75-81) provide principles for good practice. Good teachers should:

- Be good learners and learn from own practice through reflection.
- Be enthusiastic and create spaces and places to engage with students.
- Be aware of context and being scholarly in one's discipline.
- Facilitate learning by focusing on problem-solving skills and critical thinking.
- Demonstrate a respect for the students and their diverse talents.

In conclusion, while students should take responsibility for their own learning, there should be continuous support to develop the required skills and competencies related to evaluating own efforts. Good teaching and deep learning are bound to the curriculum and context which remains fairly stable in Higher Education Science disciplines.

#### *4.6.3.1 Higher Education curriculum*

As in other developing countries, the majority of the South African population is educationally disadvantaged and thus under-prepared for traditional studies in Higher Education (Bitzer 2009), especially in fundamental Sciences. The existing, traditional curriculum needs reviewing and should be adjusted to enhance student success. Entry-level curricula should be designed to facilitate a 'phased transition' during the course of the first year (Grayson 1997:116). This implies that (at the beginning of the year) the content level can be below university level (school level) and the pace of learning very slow. At the end of the year, content knowledge should be on the appropriate level and tempo to interface successfully with the following study year. Dianne Grayson (1997:115) reiterates the emphasis of transformed curricula that should be assisting students to learn how to learn, rather than addressing theoretical themes. According to Biggs and Tang (2007:7) constructive alignment is the systematically aligning "…teaching/learning activities and the assessment tasks to the intended learning outcomes, according to the learning activities required in the outcomes" and is providing meaning to the curriculum (cf. Section 4.6.1).

### 4.6.4 The interpersonal learning environment and learning strategies

The approach to teaching and learning discussed above implies that lecturers should consciously or sub-consciously adjust both their teaching and structuring of the appropriate environment to optimally meet student needs as being primarily humans (Pretorius & Jacobs 2008), but also (secondarily) potential scientists. Grayson (1997:115) advises that strategies should be implemented to create an effective learning environment. She proposes the scaffolding of content (building on previous foundations), scheduling review classes and tutorials, additional assessment opportunities and adjustments to the pace of teaching to suit student requirements. The general lack of a clear transition phase from school to university necessitates 'scaffolded' support for first-entry students (Naidoo 1999:221, Tam 2000:11 and Pape & Smith 2002:93).

Since 2005, South African universities have become involved in and are serious about the implementation of the "First-Year Experience", creating a national awareness of the challenges involved in the transition from school to university. In a public lecture by Dr. Betty Siegel (keynote speaker at the First-Year Experience Conference in Stellenbosch), addressed invitational leadership as an influence on student success and a strategy to transform institutions (2007). She focused on four themes that will enhance the student experience at an institution. Fitting of first-year students into an institution depends on specific values, as described by Siegel.

The first indicator of success is trust. Ethical relations and value systems are built upon trust among students, between staff and students, as well as among staff, by means of collaboration and common goal setting. The second pillar for success is respect: "All people are able, responsible and have value..." Treating students and colleagues with respect will assist individuals to be successful. Siegel postulates: "God, I know I must be special, because you don't make any junk." The third pillar for academic success is built on optimism. Feeling positive and optimistic is a strong release for energy and potential. Lecturers are ambassadors of their disciplines – the Chemist, the Engineer and the Mathematician. As representatives of their disciplines they should be able to go beyond the content to enhance meaning for students.

Fourthly, Siegel consolidates the above three factors in the analogy of a starfish. To be able to trust, respect and be optimistic must be intentional. Universities involve processes, policies, programmes, places and people (5Ps) (see Figure 4.10). William Purkey (founder of Invitational Education 2002) emphasises that the processes, policies, programmes, places and people must be intentionally aligned to create a healthy academic environment and contribute to the "development of the of the full potential of a student" (also see Du Plessis and Lodewyckx 2007:847). Student success hence depends on variables other than admission criteria and prior knowledge.

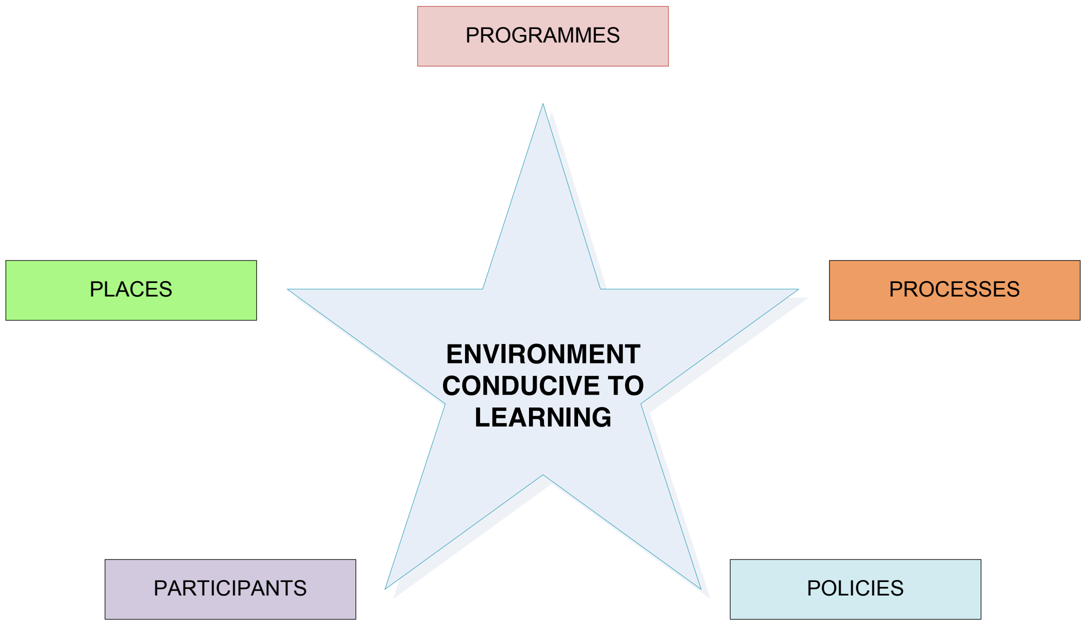


***Figure 4.10*** **The 5P-Starfish analogy for an environment conductive to learning**
(Adapted from Siegel 2007; found in Purkey 2002:1)

Siegel challenges institutions to align and become intentional in actions and procedures. Intentionally inviting is to articulate successes and fears and to be enthusiastic about research, teaching of students, engagement with communities and discovery of knowledge. University lecturers must assume that all students in their classes are good students. However, the attitude in many institutions is still: "…we only educate the best and shoot the rest." Instead, institutions should rather transform terms such as 'retention' to 'progression'.

Finally, Siegel advises universities to review curricula. Existing, historical curriculum structures need to be adjusted to enhance student success. Inadequate preparedness can be alleviated if students are susceptible to learning and experience less stress and anxiety.

### 4.6.5 Anxiety in Mathematics

Successful students in Mathematics (and Science) face the challenge of balancing confidence and anxiety. This section will focus primarily on anxiety as a factor that impedes successful learning. Confidence will be addressed in the next section, with a discussion on self-efficacy.

Students (and learners) experience a liking or disliking of Mathematics (or any other discipline) or part of course content. Eiselen (2006:69) states that such attitudes develop from previous success and mastery or from repeated emotional or traumatic reactions. Emotional reactions can be positive and result in enthusiasm when solving a challenging problem. On the other hand, negative emotions give rise to anxiety, which can result in a negative attitude, due to prolonged effort. Mitchell Lazarus (in Visser 1988:38) identified 'mathophobia' in the late seventies and explained that students often panic, feel helpless, and become mentally paralysed when confronted with problem-solving in Mathematics.

Visser (1988:38) found that individuals usually speak out freely about the difficulties they experience in Mathematics, but are reserved about other problems. Feeling of anxiety can occur at any time, and can develop from a very early age. Students with a 'mathophobia' find Mathematics so frightening and intimidating that they practically freeze. "Feeling helpless", experiencing a total aversion or even "sudden death" are some descriptions from some students. Eiselen (2006:69) expresses the view that such an attitude can become contagious. A negative attitude towards Calculus can soon become a negative attitude towards Geometry and could be transmitted to Physics or other related disciplines.

'Mathophobia', and in the same sense 'Sciencephobia' (researcher's own construction), is usually caused by a specific "language" of teaching and learning or a lack of competencies. Poor prior experience or preparedness will result in anxious feelings. Eiselen (2006:73) also mentions other factors responsible for causing anxiety, namely socio-economic background (parental attitude and support), attitude of the educator, and poor preparation. Poor achievement creates anxiety, and anxiety in turn, will result in poor achievement. Kitsantas, Winsler and Huie (2008:61) and Maree and Crafford (2005:90) indicate a decrease in achievement, with increasing anxiety levels.

Anxiety manifests in various ways and affects individuals differently. One will start biting nails or perspire excessively (physiological effect). Somebody else will worry (cognitive effect), fear (emotional effect) and even avoid classes or studying (behavioral effect). Another effect can be a negative attitude (attitudinal effect), as mentioned above (refer to Eiselen 2006:72-73). Management strategies to reduce anxiety can include encouragement and building self-esteem.

The concept of 'flow' was identified by Mihaly Csikszentmihalyi in 1975 (cf. Percival, Crous & Schepers 2003:60-71; Murphy 2005:13-26) and applied internationally in the fields of Industrial and Sport Psychology. It can also be applied to the problem of anxiety in Mathematics. The harmonious balance between challenge and skill creates flow. Those who enjoy an activity perform better. Csikszentmihalyi, cited in Percival *et al.* (2003:60), defines 'flow' as "… a temporary condition characterised by a deep sense of concentration and enjoyment of a specific activity when skill and challenge are balanced."

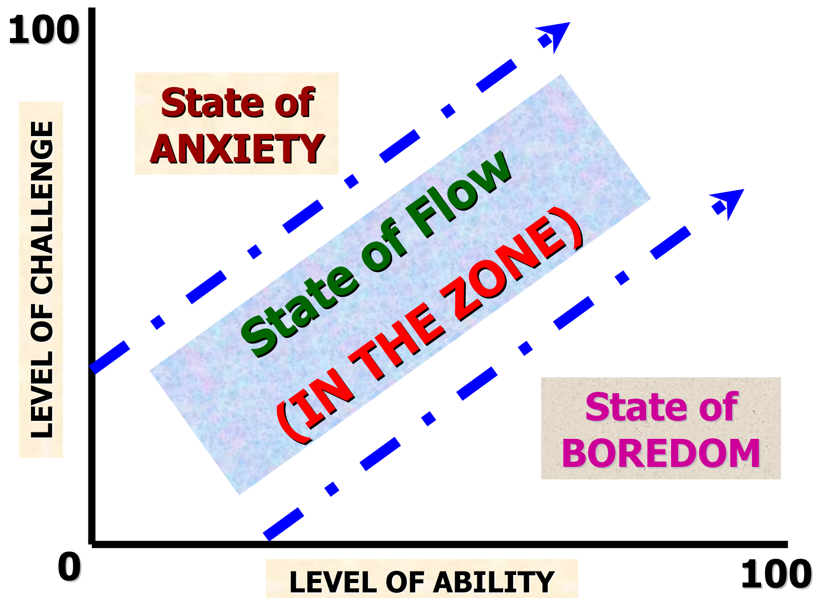


***Figure 4.11*** **The chart of flow for optimum performance**
(Adapted from Czikzentmihalyi, cited in Murphy 2005:13; Percival *et al.* 2003:61)

Being completely involved in an activity has been described as being "in the zone". This occurs when focused on the specific task at hand. The goals become clear, self-consciousness diminishes, and a feeling of potential control is experienced – "you can succeed". This is required to combat stress and anxiety often encountered in Mathematics and Science assessment. In a graphical presentation of 'flow' (Figure 4.11 above), the balance between boredom and anxiety is indicated as 'flow'.

If the challenge exceeds the capabilities (under-preparedness), students will withdraw or retract and focus on the tasks they feel comfortable with. This action creates worry, stress and anxiety and impedes good performance. On the contrary, Murphy (2005:13–26) states that students will become bored, resulting in apathy and disinterest without a challenge. Self-directed students will be able to maintain their position in the state of 'flow'. The lecturer has the task of keeping students in the state of 'flow'. Students should be in the 'zone', where the flow is optimal, an inviting environment and context created by the lecturer. Smith (in Pape & Smith 2002:99) proposes that students should take notes during a lecture, read the Mathematics text and explore available sources. Students, who believe they can be successful, will be successful and will experience being in the 'zone'.

A number of instruments have been developed to measure students' anxiety. Eiselen (2006:74) reports on these instruments, and Maree and Crafford (2005:86-92) provides evidence of the Study Orientation in Mathematics (SOM) developed in South Africa, in 1997. The test identifies students with insufficient study orientation in Mathematics. It also indicates diagnostic areas where support and development are required.

After a maths-anxiety attack, new beginning is very difficult. It sometimes seems like a lifelong handicap. According to Visser (1988:39) and Eiselen (2006:72), this emotional and intellectual blockage, limit students' study and career options and can result in a need for student counselling. The anxiety is linked to personality traits (cf. Sections 4.3.5 & 4.3.6) of which Neuroticism, Introversion and low Openness to Experience immediately come to mind. To change or remedy anxiety implies a change of personality – this challenge will be easy to tackle at Higher Education level. The answer might lie in developing self-efficacy in Mathematics.

## 4.7 SELF-EFFICACY

In this section, the fifth non-cognitive factor associated with academic achievement, namely self-efficacy, is discussed (see the flow in Figure 4.12). Maree (2005:89) mentions that previous success usually builds high self-esteem, which in turn, creates confidence to enhance performance in future, tasks. Albert Bandura (in Bandura 1994:74 and Pajares & Schunk in Aronson 2002:13) identifies the presence of self-perception to pursue goals. The choices made by individuals are influenced by what they believe they are capable of. The belief system also directs effort to expand, the perseverance to continue and finally the behaviour of an individual. Individuals can create their own anxiety or optimism. The Roman poet Virgil probably was correct in stating "They are able who think they are able." Gaskill and Hoy in Aronson (2002:188) and Mills, Pajares and Herron (2007:418) explain that students with high perceptions of their ability challenge themselves, whereas self-doubters will resign or avoid the situation to preserve self-worth.

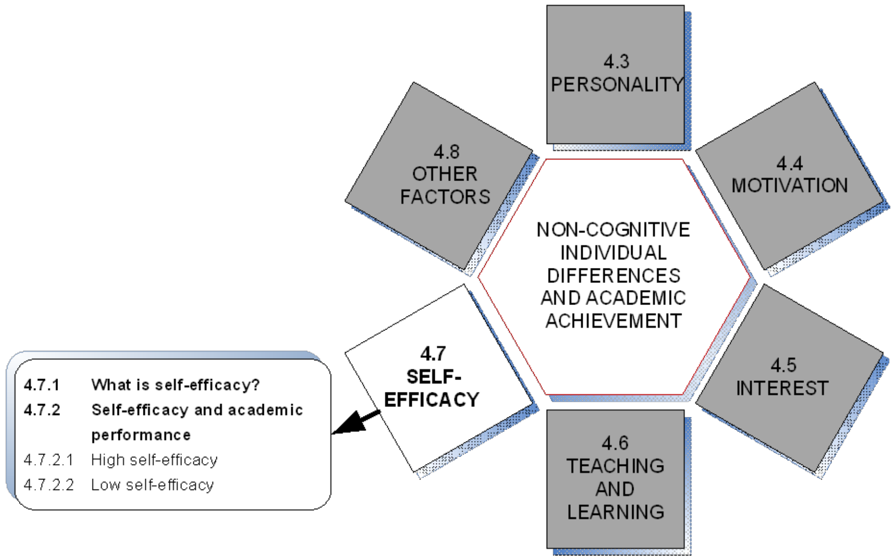


***Figure 4.12*** **Self-efficacy and academic achievement**

### 4.7.1 What is self-efficacy?

Gaskill and Hoy (2002:186) refer to self-efficacy as an individual's belief about his/her own or personal abilities to execute a particular task, whereas, Pajares (1997:15) defines the concept as "…a context-specific assessment of competence to perform a specific task" (also refer to Bandura 1986:140). Another opinion is added by Gaskill and Hoy (2002:186), with: "The greater people's sense of self-efficacy in a given domain, the more effort they will exert and the more successful they are likely to be."

According to Gaskill and Hoy (2002:186), self-efficacy focuses on three aspects, namely i) the belief and knowledge of own ability, ii) the focus on a specific task at hand and iii) the aspiration to be successful. Individuals should be able to judge a task and evaluate own competence to accomplish the given task. Students will feel self-efficacious if they can visualise themselves as being successful. This 'gut' feeling will determine the level of effort put into the task. Self-concept, on the other hand, is a broad construct that includes all perceptions of the self and is not focused on a particular task. Bandura (1986:14) describes self-concept or self-esteem as "…the evaluation of such competence and the feelings of self-worth associated with the behaviors in question."

According to Gaskill and Hoy (2002:187), Bandura (a social-learning specialist) indicates that self-efficacy develops from four sources, namely:

- Mastery of own and direct experiences acts as a powerful source of efficacy information. This creates a memory of being successful and raises efficacy beliefs.

- Physiological and emotional arousal - being excited and 'psyched-up' raises efficacy.
- Vicarious experiences and reference to the perception that somebody else is successful will also increase own efficacy.
- Verbal persuasion will enhance self-efficacy, depending on the credibility of the persuader. For example, encouragement or boosts such as a 'pep talk' can urge individuals to attempt harder.

### 4.7.2 Self-efficacy and academic achievement

Self-efficacy has significant power to predict and explain academic achievement according to Pajares (2002:3) and Mills *et al*. (2007:417). It is closely related to self-concept, anxiety and self-confidence, as well as background. These constructs are difficult to separate from one another. The pedagogical challenge is two-fold: To firstly, motivate students to believe in their own abilities, and secondly, to motivate lecturers to create an environment conducive to learning and to provide strategies to improve students' self-efficacy. Educational processes should also provide the opportunities for successful learning experiences.

Landis, Altman and Cavin (2007:129) mention that if a lecturer can instill appropriate study skills in students, their self-efficacy will improve, which in turn, will move expectations from external to internal and own expectations. Kitsantas *et al.* (2000:64) relates self-efficacy and locus of control with an accompanying increase in relevancy in later years of study. As mentioned previously, Biggs and Tang (2007:41) emphasise that self-regulated students are active participants in their own learning, which occurs when effective teaching takes place. Academic achievement may therefore relate strongly to high self-efficacy.

#### *4.7.2.1 High self-efficacy*

According to the research findings of Landis *et al.* (2007:127), high self-efficacy and good academic achievement correlate significantly with students being inclined to seek help when required, resulting in less procrastination. Some researchers mention a strong relationship between academic success, high self-efficacy and persistence. Individuals with a high sense of self-efficacy aim high, but also recover from setbacks or failures quickly. Mills *et al.* (2007:417-418) explain that such students will manage difficult and threatening situations with ease.

An indication by Pajares (2002:3), that students with high self-efficacy will show increased persistence and display flexible ways to adjust to learning strategies, in order to self-regulate their learning and attain high intellectual performance. Research by Golden (2007:14) shows that high self-efficacy prompts individuals to assist or support other students. Involvement with others and observing their achievements will increase self-efficacy (cf. vicarious experiences mentioned above).

In a postulation from Landis *et al*. (2007:129), self-efficacy is a characteristic of a diligent and successful student. Such students make better use of a variety of study skills; and are able to adjust comfortably and be successful in Science studies. They also display a high level of help-seeking attitude.

#### *4.7.2.2 Low self-efficacy*

Individuals with low self-efficacy lose faith and become stressed and depressed. Mills *et al*. (2007:418) reports that such students will only attempt uncomplicated tasks and avoid complex tasks. Howard Margolis (2005:221-238) reviewed students with low self-efficacy and proposes the following actions to improve self-efficacy: begin lecturing at the level of the student and increase the independence level; reward effort and success; and remind students of previous successes. In addition struggling students should be treated with respect and dignity.

The rapport between students and lecturers was reviewed by Downey (2008:57), who agrees that at-risk students require a healthy interpersonal relationship with their lecturers. Lecturers should provide academic support and foster a sense of pride in student efforts. Ayayee and Sanders (2000:2) support this statement and remark that low achievers view themselves as failures, which inhibits learning and also influences the choices made by such students. Self-efficacy influences choice of majors and career decisions. Lebedina-Manzizoni (2000:708) mentions that unsuccessful students usually blame the institution, as they are uncertain about the choices they make. Research by Bandura (1987:18) also indicates that the choice in majors of USA students' reflects areas where they feel competent. This can pose a problem in the South African context, as career counselling and guidance is not addressed sufficiently at school level.

Bandura (1987:19) indicates that self-efficiency seems to be a better predictor of Mathematical interest than prior achievement or expectations. Expectations and confidence in performing in Mathematics (as a general task) is close to own capabilities and can differ from performance in a specific mathematical task. Pajares (2002:120) also reports that male students are usually more confident in Mathematics and Science than female students, implying that there are other indicators also influencing success at university level.

## 4.8 OTHER FACTORS INFLUENCING ACADEMIC ACHIEVEMENT

In this section, other non-cognitive factors associated with academic achievement will be mentioned and outlined briefly as shown in the flow diagram below (Figure 4.13).

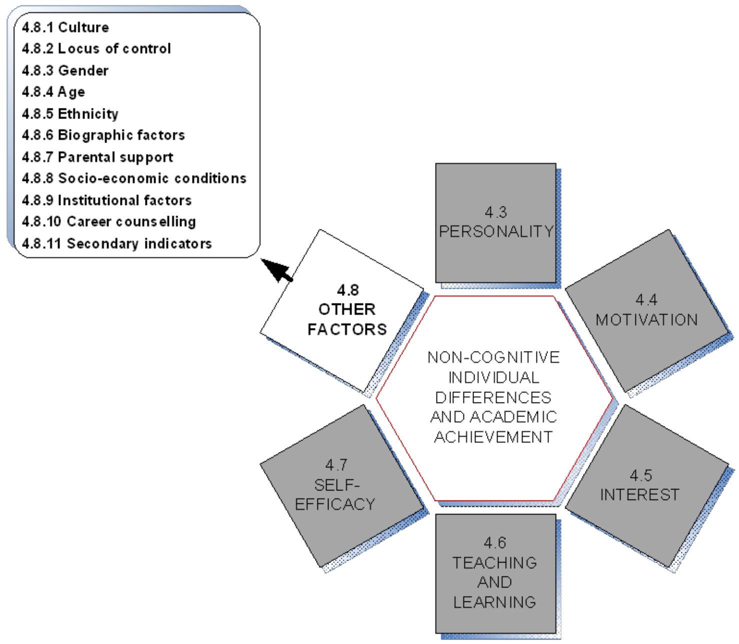


***Figure 4.13*** **Other factors and academic achievement**

The preceding discussions provided a literature review of the influence of personality, motivation, interest, teaching and learning, and self-efficacy on academic achievement. In a study by Hay and Jama (2004:243), it was found that successful students do not wish to operate in groups, yet other (weaker) students rely on successful students for optimum functioning in groups. The aforementioned and other facts are mostly not taken into account when students are expected to perform well. This section will briefly mention a few other factors that can also influence academic achievement.

### 4.8.1 Cultural and academic achievement

According to Mtetwa (2006:479) culture can be described as "…the totality of how a given group of people experience their world and share and express those experiences among themselves." Hay (2008:943) observed student behaviour in a lecture hall and found that the South African culture differs from that of the USA or UK. Self-directedness, assertiveness and problem-solving are skills developed and acquired in other Western educational systems.

In the South African context, where 79% of the population is Black, Soudien (2008:668) describes the culture as African. In such a culture, contributing own ideas is often regarded as violating the concepts that maintain harmony. According to Hay (2008:943), Black students share ideas rather than debate them and will not challenge lecturers. They feel uncomfortable in the discourse style of university lectures. Nodding of the head does not necessarily mean that a student understands. It may simply imply that he/she is paying attention to you. Black students are scared to ask and hesitate to answer questions.

Hay (2008:944) postulates that OBE contradicts African culture. The fact that lecturers do not know students' names and are unable to pronounce African names, alienates students. Students in the survey conducted by Hay mentioned that lecturers use examples from the everyday life of Whites, and that Black students are not familiar with these. Van Rooyen (2001:186) remarks that African students are fairly at-risk from the beginning. They struggle to express their needs in English, and therefore avoid asking questions. Garaway (1994:104) also emphasises that lecturers should be able to bridge the technological Mathematics and Science from Western society to the life and culture of the non-Western student.

In studies performed internationally, many informal Mathematical processes performed by uneducated individuals have been documented. Mtetwa (2006:150) reports that measuring cups of rice in Liberia, cultural trading in Africa, basket weaving and constructing buildings generate Mathematical ideas, while the practice of lobola (dowry) provides cultural context to computation. Cultural diversity indicates a varied manifestation of the locus of control.

### 4.8.2 Locus of control and academic achievement

Schepers (1995); Muller and Schepers (2003a:254) and Landis *et al.* (2007:129) state that internal locus of control (control over life events), together with high self-efficacy, are important determinants of good results. Locus of control refers to "…where control over subsequent events reside(s)" (Sattler 2001:132). External locus of control indicates that experiences such as fate, luck and chance determine outcomes, whereas internal locus of control implies that individuals control their own destiny.

Students with an internal locus of control will even attend classes when not feeling well (cf. 4.2.2 and Figure 4.11 p.161). They will begin doing their assignments at an earlier stage and in general, will put effort into their studies. Hay and Jama (2004:243) explain that such students will take notes and make summaries, read attentively and use mind maps. Percival and

Schepers (2003b:254) developed a Locus of Control Inventory (2003:255) that proves to be highly reliable for South African students (reliability of 0.866). Enslin, Button, Chalkane, De Groot, and Dison (2006:441) state that students who take ownership of their own destiny will ask for help and have a positive approach towards the future. Finally, Gifford (2006:20) adds that students with self-worth will take control over their own lives. It should be noted that the African culture also does not allow women to take too much control.

### 4.8.3 Gender and academic achievement

In studies performed by Wigfield and Eccles in Aronson (2002:176), Hay and Jama (2004:239) and Eiselen (2006:86) the differences between male and female students are mentioned. They indicate that males are better at problem-solving in Mathematics and more confident about their perceived ability than females. They function independently and attribute success or failure to themselves. According to Eiselen (2006:87), male students attach more importance to Mathematics than females. Ayayee and Sanders (2000:2) suspects that this might still be as a result of societal belief that Mathematics is more suitable for males. Viljoen, Schepers and Van Zyl (2001:52) state that males are more interested in obtaining academic qualifications, while the broader value of learning interest females.

The majority of females will only choose Mathematics at university level if they really achieved well at school. Studies by Hay and Jama (2004:239) and Cavallo, Rozman and Potter (2004: 288-300) show that females feel anxious and negative about Mathematics and will blame failure on a lack of knowledge. Eiselen (2006:86) indicates that the self-efficacy measurement will serve as good predictor of Mathematical achievement with females. When Potter, Van der Merwe, Kaufman and Delacour (2008:1273) conducted research on Engineering students, they found that female students struggled with graphics. The reason for this problem seemed to be social stereotyping and not a lack of knowledge and skills, as expected. The Higher Education Research Institute (2007) indicates that gender shows relevance to achievement.

### 4.8.4 Age and academic achievement

Age makes a difference when studying Mathematics and Science. Young students have recent knowledge (directly from school), but also experience problems with the transition from school to university. On the other hand, older students studying Mathematics (or Science) after some time will experience difficulty, but they mostly have such a positive attitude that they are able to overcome difficulties with sufficient practice. Eiselen (2006:72) found that young students tend to withdraw more easily when they are unsuccessful, while older students will persist.

### 4.8.5 Ethnicity and academic achievement

Ethnicity is always a contentious issue, and this research will not attempt to give a political opinion on racial occurrences. It has to be mentioned, however, that in the South African socio-economic state, race and the inequalities resource distribution impact on academic achievement. The fact that schools in rural areas, where mostly Black people live, are under-staffed, and teachers are under-qualified to teach specifically Mathematics and Science, cannot be ignored (Eiselen 2006:85; Dawes, Yeld & Smith 1999: 98).

In the United States of America, Astin (1999:587) indicates that Black students were more successful at predominantly Black colleges where they persisted longer than when attending predominantly White institutions. In a study by Cross and Johnson (2008:311), xenophobia on campuses in South Africa is recognised as an issue, and Soudien (2008:669) remarks that Black students from rural areas feel like strangers when they return home.

### 4.8.6 Biographic factors and academic achievement

In various research studies, other biographical factors (excluding race, gender and age) are identified as health, marital status; involvement and financial aid are some of the factors to influence academic achievement. Astin (2005:10) propagates that students should live in residences on or nearby campus, as this correlates significantly with retention rates. More students persist in religious institutions, while those from small towns persist better in smaller institutions. Enslin *et al.* (2006:439) developed a Biographical Questionnaire (BQ) and report favourably with regard to South African information on profiling students. They found that knowledge of background and home environment provide students with a specific context and can guide future decisions.

### 4.8.7 Parental and broad community support and academic achievement

Lebedina-Manzoni (2000:708) believes that many students fear to disappoint their parents, and that this may distract them from focusing on their studies. Hay and Jama (2004:239) indicate that students with sufficient support from parents, friends and family, as well as emotional, financial and religious support, achieve better academically. In the current economic situation, there is evidence (cf. McFarlane in Mail and Guardian 6-12 May 2005:4) that parents also pressurise students to graduate and begin earning a salary.

First-generation students face many challenges more so for South African students who are the first in their family to attend a Higher Education institution (cf. Section 3.3.2). Home environments, where there is a lack of comprehension of studies in Higher Education have a negative influence on success (Hay & Jama 2004:239; Maree 2009:279). Investigations indicate that the financial burden is one of the major influences impacting on student academic achievement (Hay & Jama 2004:239).

### 4.8.8 Socio-economic conditions and academic achievement

As mentioned above, many students are first-generation students and live off-campus. McFarlane in Mail and Guardian (23-30 December 2008:25) identifies factors such as commuting to campus, noisy conditions at home or inadequate study space as impeding optimum academic achievement

### 4.8.9 Institutional factors and academic achievement

Students are admitted to universities before having been afforded the time to become acquainted with the institution. Alternatively institutions also admit students without knowing students' background. There should be a student-institution 'fit' (Eiselen 2006:91), as well as an institution–student 'fit', for ultimate congruency (cf. Holland Section 4.3.2). Astin (1999b:518), Tinto (2008:14) and Eiselen (2006:91) list institutional factors that enhance student success. The student should:

- Be socially and academically integrated.
- Identify with peer groups (although Science students often feel alienated).
- Be integrated in the institutional culture.
- Be an involved student.

The institution should:

- Facilitate congruence with students.
- Be cognisant of the various student backgrounds (social, economic and cultural).
- Provide support and assistance (especially in Mathematics).
- Provide appropriate technological resources.
- Use culturally sensitive teaching techniques.
- Actively involve students in learning.
- Support students with interventions, such as remedial Mathematics classes, study skills and time management assistance.

The role of student orientation in Higher Education institutions may also influence their transition into Higher Education (Borden and Evenbeck 2005). Strydom and Mentz (2008:1088) identify the trends below. Orientation of new first-year students should:

- Be of an academic nature to introduce the academic environment.
- Accommodate the diverse student population, and be flexible, innovative, purposeful and efficient.
- Increase family attendance and involvement.
- Focus content and activities on academic success.

Institutions are admitting students; these students are inducted into the new environment, with the assumption that the students are sure that they have made the correct selection of programmes. The counselling and support with decisions on programmes and the future should not be underestimated.

### 4.8.10 Career counseling and academic achievement

Traditionally, career counselling is available to students who can afford it, and Maree and Beck (2004:81) explain that this service is based on psychometric tests that guide choices. Only a small number of tests have been developed for the multi-cultural South African population. Counselling and guidance to make decisions on careers and study fields should form part of preparation at school level (Akdere and Foster 2005:57). Currently, this is not happening, as there are only a few qualified teachers to assist learners. Knowledge of the wide spectrum of careers is limited and, in the researcher's own experience, many students do not accept the advice provided by counsellors.

Students are admitted to Higher Education without having been profiled, and will only be referred to counsellors after having failed or labelled as at-risk students. Enslin *et al*. (2006:442) mention that an intrinsic motivation such as a definite and clear career-path have career-focused students achieve well. Coertse and Schepers (2004:64) add that career-maturity manifests in study habits and adaptability. Career certainty and interest in the chosen programme would indicate academic achievement as would other indicators serve as positive stimuli.

### 4.8.11 Secondary indicators of academic achievement

The following factors will not be discussed, yet are mentioned as important indicators of academic achievement:

- Smaller class sizes (Fenollar, Román, and Cuestas 2000:886; Wimshurst & Allard 2008:696).
- An informal student network, such as the 'buddy system' (Potter *et al*. 2008:1269).
- The number of modules that students register for (Lourens & Smit 2003:174).
- Emotional intelligence (Parker, Hogan, Eastabrook, Oke & Wood. 2006:1329-1336).
- Expectations and choices of students and parents (Maree and Crafford 2005:88).
- Time management (Potter *et al*. 2008:1262).
- Social relations, also of students with lecturers (Potter *et al*. 2008:1262).

## 4.9 SYNTHESIS

While the first year is the most crucial year to affect academic student achievement, McKenzie *et al*. (2004:95-111) acknowledge that students develop particular attitudes and approaches during this year. The transition period in the first year is problematic and students require general mental ability and skills to succeed, as well as the will to be successful. When all the 'new' things in Higher Education become tough for first-year students, they need to believe that they can succeed (Pulford & Sohal 2005:2), have the confidence to keep persevering and know that support is available. Grayson (1997:107) expresses the notion that students can be successful in Higher Education if they "…undergo a process of enculturation to university life."

From the literature study, it became evident that the role of personality and other non-cognitive indicators of academic success are meaningful. The trait approach as a predictor of academic achievement was discussed (cf. Section 4.3.3). Research on individual differences in educational environments emphasised two areas: Firstly, the relationship between personality traits and educational-related constructs, such as academic achievement or success, and the choice of study and learning styles. Secondly, application of the paradigm of individual differences to describe the student characteristics in specified study fields, according to the Holland's model (cf. Section 4.3.2).

The BTI provides guidelines for applying the Big Five traits (Openness to Experience, Conscientiousness, Extroversion, Agreeableness and Neuroticism) in the context of South African multi-cultural societies (cf. Section 4.3.4), and to apply motivational knowledge. The various strategies to motivate students and cultivate an interest in academic achievement (cf. Section 4.5); in order to produce self-motivated and self-directed students depend on teaching and learning (cf. Section 4.4). Engaging students and encouraging deep learning requires a shift from teaching fundamentals to teaching for success (cf. Section 4.6). Awareness of the importance of anxiety in Mathematics (cf. Section 4.6.5), self-efficacy (cf. Section 4.7), cultural differences (cf. Section 4.8.1) and locus of control (cf. Section 4.8.2) assists in counselling and student support. The role of gender (cf. Section 4.8.3), age (cf. Section 4.8.4), ethnicity (cf. Section 4.8.5) and other socio-economic factors (cf. Section 4.8.6 to 4.8.11) in academic achievement should also be noted.

Placement of students to promote academic achievement is dependent on fitting the student into the institution. Entry into the institution occurs with an interface. One facet represents the institution, which is rigid, stable and stationary. The other facet is the ‘new’ student with his/her cognitive and non-cognitive abilities and attributes, dynamics and uncertainties, and many expectations. In aligning the student with the institution, cognisance of the available information on both entities has to be taken into account, to make appropriate fitment possible.

This chapter considered non-cognitive individual differences of students. Some of the students’ non-cognitive abilities and attributes can be determined prior to placement in an academic programme: personality types and traits, and motivation and interest in the field of study, all of which can be measured with various inventories. Characteristics such as personality type, scores on the Big Five, Mathematical anxiety, interest, self-efficacy and motivation measurements can serve as indicators of academic success in Science.

The role of the teaching and learning in Higher Education placed deep and surface learning in relation with academic achievement. The successful student (cf. Section 4.6.1) is self-directed, motivated and interested. Many students enter universities without having all the ‘tools in their toolbox’ and require institutional assistance and support. They also require good teaching. Institutional preparedness to facilitate and teach for success requires commitment from both management and lecturers, resources to appoint suitable lecturers and additional student support systems (cf. Section 4.6.3). The institution should be committed to teaching and creating an environment conducive to learning and must develop strategies to cultivate an environment where student success is a priority (cf. Section 4.6.4).

The cognisance and knowledge of factors related to success, guides the development of a framework for placement of students. The diagnosis of deficits that jeopardise integrating the student into the institution provides an opportunity to mould, shape and change attitudes, and possibly to adapt practices and profiles to ensure alignment. Ultimately, the integrating process may take time, and therefore a framework for placement is proposed.

# CHAPTER 5

## *RESEARCH DESIGN AND METHODOLOGY*

### 5.1 INTRODUCTION

In this chapter, the research design and methods used in the empirical investigation are clarified. The chapter is divided into five sections. Firstly, the role of this specific section in the study is contextualised. Secondly, the research design and objectives are stated. Thirdly, the characteristics of the participants are described, and fourthly, the instruments used for measurements and data collection are discussed. Finally, the statistical analyses techniques are described.

The research comprises different phases Figure 5.1 depicts the stages in this particular phase of the study:

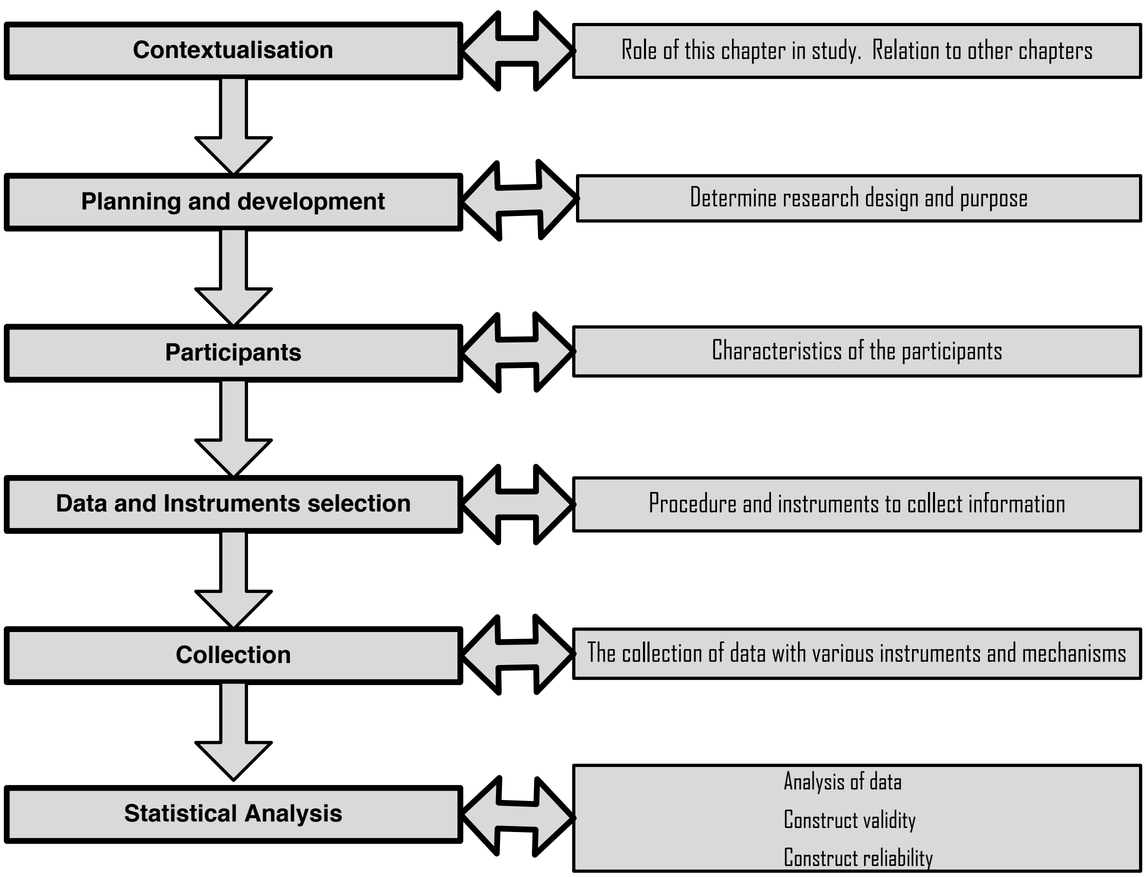


***Figure 5.1*** **Stages in the research design**
(Adapted from Eiselen 2006:103)

## 5.2 THE RESEARCH APPROACH

The empirical component of this study adopted a quantitative approach, where the focus fell on identifying variables that may be used to predict student success in fundamental Science modules. The quantitative approach is based on the assumption that the variables of interest can be quantified and measured. The approach taken in this study may be typified as post-positivist, which presumes that an external reality exists independent from the researcher, but that this reality cannot fully be known. From this perspective, the aim of research is to build models and theories that allow scientists and practitioners to make sense of the complexity of the world that they operate in. Such models and theories explicate the main variables of interest, integrate them into meaningful frameworks, and provide guidance for intervention. However, the post-positivist view does not aim to develop theories, models and frameworks that reflect absolute truths about reality. From this perspective, the outcome of research may be judged with respect to the usefulness (substantively and practically) of the models and theories that it generates. Useful frameworks, models, and theories can be expected to generate new research and to allow predictions that conform to empirical observation.

## 5.3 THE RESEARCH PURPOSE AND EMPIRICAL RESEARCH AIMS

### 5.3.1 The research purpose

The purpose of this investigation is the establishment of a framework for the placement of first-year students in Science programmes. Two sources of information guide the development of the framework, namely i) a literature review, consideration of policy directives and student abilities, and ii) empirical research focusing on student attributes that contribute toward academic success. The review of the literature and relevant policies are covered in the preceding chapters (cf. Chapter 2 to 4). In the sections that follow the focus falls on the specific objectives of the empirical investigation.

The overarching goal of the empirical component is the identification of valid and reliable predictors of student success in Science modules. The following empirical research objectives are pursued in this study:

- To examine the relations between biographical variables (i.e. gender, age, home language, ethnicity) and first-year performance in Science modules.
- To examine the predictive value of school performance (total Grade 12-score) with regard to success in first-year Science modules.

- To correlate school performance in individual subjects (i.e. Mathematics, Physical Science and English) with first-year performance in Science modules.
- To examine the predictive value of an independent scholastic aptitude test, namely the Stellenbosch University Access Test with regard to success in first-year Science modules.
- To examine the predictive value of personality traits, as measured by the Basic Traits Inventory, with regard to success in first-year Science modules.
- To examine the predictive value of the Study Orientation in Mathematics Tertiary, as measured by the SOMT Inventory, with regard to success in first-year Science modules.

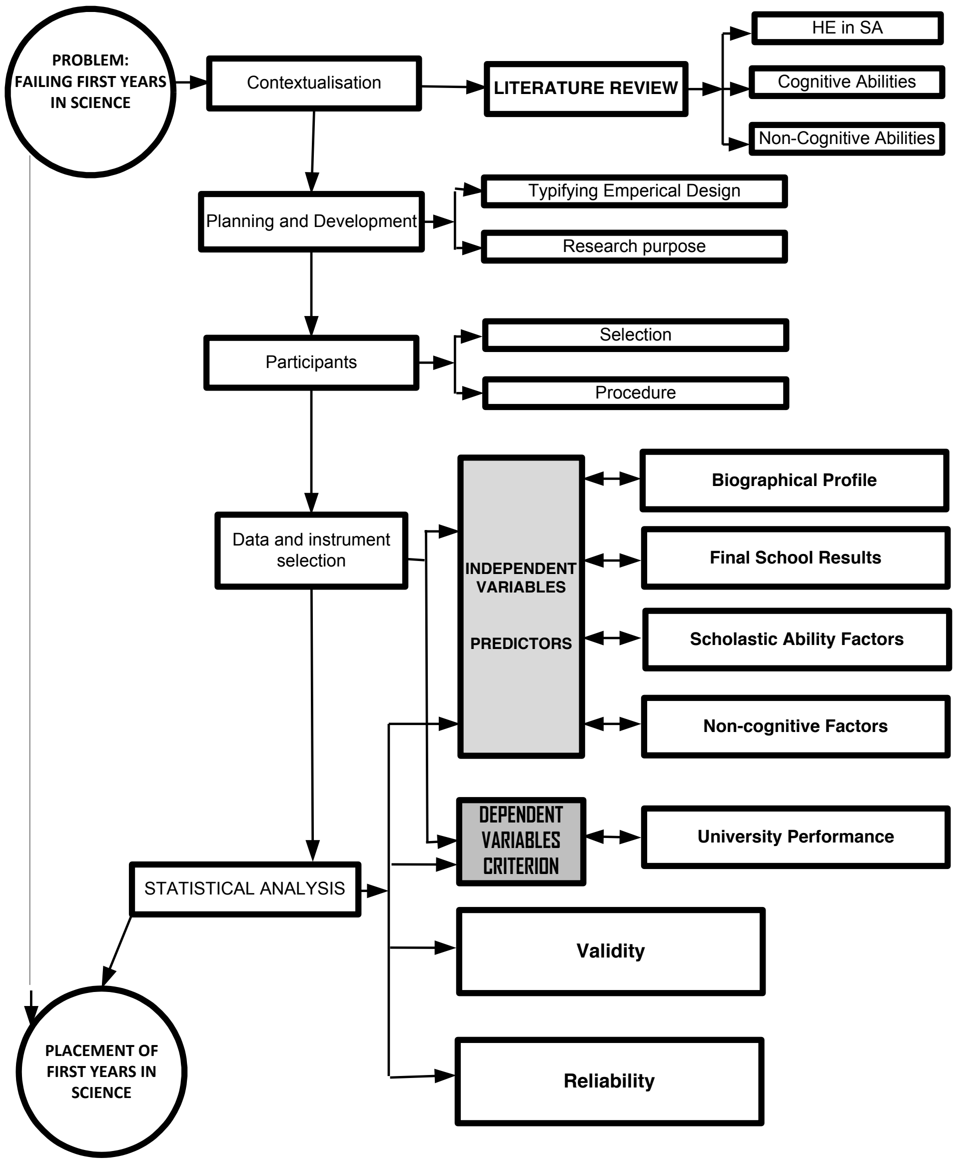


***Figure 5.2*** **The research method**

Figure 5.2 indicates the course of this chapter as compiled by the researcher.

## 5.4 PARTICIPANTS

The target population included all first-year students registered for three fundamental Science modules (i.e. Mathematics, Chemistry, and Physics) at a residential university in Gauteng, South Africa. Participants were drawn from the 2006 to 2009 cohorts of first-year students registered for these modules. These students were registered for programmes housed in three faculties, namely Science, Engineering, and Health Sciences. Note that although the university confers National Diplomas (ND) and Bachelors degrees, this current research gathered data from degree students only.

Table 5.1 summarises the distribution of enrolled students across the different fields of study across all four cohorts.

**Table 5.1** ***The First-year Population Data (2006 to 2009)***

| Field of study | 2006 cohort | 2007 cohort | 2008 cohort | 2009 cohort | Growth from 2006 to 2009 (%) |
|---|---|---|---|---|---|
| **Total first year intake** at institution | 7 962 | 8 587 | 10 006 | 13 424 | 40.0 |
| Total 1st year intake in Faculty: **Science** | 751 | 805 | 569 | 1 113 | 32.5 |
| Total 1st year **degree** intake in Faculty: Science | 680 | 685 | 449 | 935 | 27.3 |
| Total 1st year intake in Faculty of **Engineering** | 1 552 | 1 619 | 1 433 | 1 685 | 7.9 |
| Total 1st year **degree** intake in Faculty of **Engineering** | 490 | 494 | 431 | 610 | 19.7 |
| Total 1st year intake in Faculty of **Health Sciences** | 490 | 560 | 566 | 634 | 22.7 |
| Total 1st year **degree** intake in Faculty of **Health Sciences** | 223 | 248 | 251 | 254 | 12.2 |
| % of **total intake** represented in the sample | 10% | 7% | 4% | 5% | |
| **Total participants** in research | 773 | 628 | 364 | 715 | |

The total number of participants in the study represented ranged from 10% to 5% of the total first-year intake at the institution. An exception is noted in 2008, where a drop in the number of students that enrolled for Science and Engineering can be observed.

To allow for generalisation of the research findings, the participants must be representative of the population of students to which one wishes to generalise. The present group of participants was restricted to first-year students at one university that attended the orientation programme at the beginning of the academic year. Although only degree students from one university participated in this investigation, it is reasonable to expect that other South African universities experience similar problems with respect to the placement of students. Moreover, it appears reasonable to expect that the participants in the present study will be similar to students at other universities with respect to age, gender distribution, and exposure to the same national school context. In this respect the findings of the present study are likely to be of relevance and interest to researchers and practitioners beyond the borders of the institution where the research is conducted.

Table 5.2 reflects the total enrolments in the fundamental Science modules used in this investigation.

**Table 5.2** ***Total class sizes in Fundamental Science Modules (2006 to 2009)***

| **Module** | **2006 cohort** | **2007 Cohort** | **2008 cohort** | **2009 cohort** |
|---|---|---|---|---|
| Total number of students registered in first year **Mathematics** | | | | |
| Mathematics 1A | 876 | 456 | 404 | 918 |
| Mathematics 1C | 0 | 0 | 110 | 263 |
| Total number of students registered in first year **Chemistry** (% in sample) | | | | |
| Chemistry 1A | 844 | 517 | 304 | 461 |
| Chemistry 1C | 0 | 244 | 234 | 440 |
| Total number of students registered in first year **Physics** (% in sample) | | | | |
| Physics 1A | 603 | 425 | 332 | 468 |
| Physics 1C | 88 | 125 | 190 | 275 |

Figure 5.3 depicts the distribution of the participants across field of study in the three faculties. The students in the Faculty of Science are divided into four fields of study, namely, Mathematical Sciences, Physical Sciences, Life and Environmental Sciences and Information Technology.

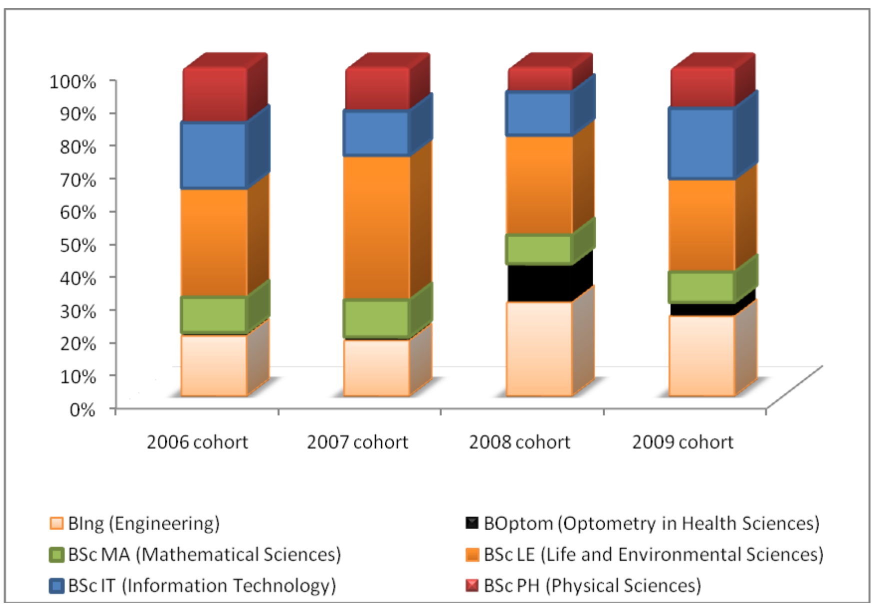


***Figure 5.3*** **The distribution of participants across fields of study**

Table 5.3 summarises the biographical details of the participants in this investigation with respect to gender, age, home language, and ethnicity. For the 2006 cohort there were 773 useable student profiles, for 2007 there were 628; for 2008 there were 364, and in 2009 there were 715. These students (n = 2480) participated in this investigation in different capacities. Note that complete data were not available for all participants on all the variables of interest in the study. In the results chapter (cf. Chapter 6) it is clearly indicated how many participants' data were used for each of the analyses that are reported.

**Table 5.3** ***The Biographical Variables of the Sample of First-year Students (2006 to 2009)***

| Variable | Detail | 2006 cohort % (n) | 2007 cohort % (n) | 2008 cohort % (n) | 2009 cohort % (n) | Total group % (n) |
|---|---|---|---|---|---|---|
| **Total participants (n )** | | 773 | 628 | 364 | 715 | 2480 |
| **Gender distribution** | **Male** | 64.6% (499) | 60.5% (381) | 60.3% (219) | 54.4% (389) | 59.0% (1488) |
| | **Female** | 35.4 % (274) | 39.2 % (247) | 39.7 % (145) | 45.6 % (326) | 41.0% (992) |
| **Ethnic distribution** | **Black** | 41.0 % (317) | 48.3 % (303) | 51.4 % (186) | 66.2 % (474) | 54.0% (1281) |
| | **Coloured** | 3.0 % (23) | 2.4 % (15) | 1.0 % (4) | 2.8 % (20) | 3.0% (62) |
| | **White** | 49.4 % (382) | 40.5 % (254) | 38.1 % (139) | 5.5 % (39) | 27.0% (814) |
| | **Asian** | 6.6 % (51) | 8.8 % (55) | 9.5 % (35) | 25.5 % (182) | 16.0% (323) |
| **Home language** | **English** | 30.0 % (232) | 30.6 % (192) | 47.5 % (173) | 27.0 % (195) | 31.0% (792) |
| | **Indigenous African** | 32.9 % (254) | 43.5 % (273) | 37.1 % (135) | 65.5 % (468) | 50.0% (1130) |
| | **Afrikaans** | 32.1 % (248) | 23.6 % (148) | 15.1 % (55) | 4.5 % (32) | 16.0% (483) |
| | **Other** | 5.0 % (39) | 2.4 % (15) | 0.2 % (1) | 2.8 % (20) | 3.0% (75) |
| **Age (Years)** | **18-19** | 8.0 % (62) | 31.0 % (195) | 86.3 % (314) | 83.3 % (596) | 54.5% (1165) |
| | **20-21** | 50.2 % (388) | 43.9 % (276) | 10.4 % (38) | 14.5 % (104) | 28.7% (806) |
| | **≥ 22** | 41.8 % (323) | 25.1 % (158) | 3.3 % (12) | 2.2 % (16) | 16.8% (509) |

The following trends from Table 5.3 and Figure 5.3 are noteworthy:

- The proportion of Black students increased from 41% to 66% from 2006 to 2009.
- There is a dramatic decline in White (from 40% to 5.5%) and Afrikaans students (from 32% to 4.5%) from 2006 to 2009.

- The Coloured student participation is very small, but is a proportional representation of the Coloured population at the university.
- There is a shift in the first language spoken by students (Afrikaans and English are decreasing, whereas indigenous African languages are increasing).
- The age distribution shifted from a relatively older group (e.g. in 2006, 42% were older than 21 years) to younger students (e.g. in 2008 and 2009 more than 80% were 19 years and younger).
- Most students (35%) were registered for the BSc (Life and Environmental Sciences) programme.

In summary, the participants were predominantly male, Black, aged between 18 and 19 years, and spoke an indigenous African language as their home language.

## 5.5 PROCEDURE

Most of the first-year students registered for fundamental Science modules (i.e. Mathematics, Physics and Chemistry) in the 2006 to 2009 cohorts, attended an academic orientation programme at the beginning of the academic year. Participants were drawn from this pool of students. During the orientation programme time was allocated for the collection of data pertaining to the study. Due to constraints with respect to time, logistics and budget it was not possible to collect data with the same instruments across all four cohorts. Table 5.4 shows the variables present in the relevant cohorts. The Stellenbosch University Access Test was only conducted in 2008 and 2009 and the SOMT was not administered in 2009.

## 5.6 DATA COLLECTION AND MEASURING INSTRUMENTS

In this section, the collection of data, processes and instruments are discussed. Table 5.4 summarises the distribution of data collected.

**Table 5.4** ***The Collection of Data per Cohort (2006 to 2009)***

| Variable | 2006 cohort | 2007 cohort | 2008 cohort | 2009 cohort |
|---|---|---|---|---|
| Field of Study | √ | √ | √ | √ |
| Gender | √ | √ | √ | √ |
| Age | √ | √ | √ | √ |
| Home language | √ | √ | √ | √ |
| Ethnicity | √ | √ | √ | √ |
| M-score / APS | √ | √ | √ | √ |
| Grade 12 English | √ | √ | √ | √ |
| Grade 12 Mathematics | √ | √ | √ | √ |
| Grade 12 Physical Sciences | √ | √ | √ | √ |
| SU Access Test Mathematics | | | √ | √ |
| SU Access Test Physical Science | | | √ | √ |
| BTI | √ | √ | √ | √ |
| SOMT | √ | √ | √ | |
| University performance in Fundamental Science modules | √ | √ | √ | √ |

### 5.6.1 Biographical profile

The official application and registration forms of the institution served as sources of biographical information of the participants. Data were captured for the following variables: gender, age, home language and ethnicity (see Tables 5.3 and 5.4).

### 5.6.2 Grade 12-school results

Universities admit first-year students on the basis of a certified copy of the final school results prior to registration at the institution. The symbol statement of the Senior Certificate (until 2008) and the National Senior Certificate (from 2009) are the official documents issued by the DoE on completion of the final school examination.

The university converts the individual Grade 12-subject results to a value between 0.5 and five (5) to calculate a total M-score (Matric score). The M-score applies to all Grade 12-learners who wrote the Senior Certificate (2006 to 2008). The first group of students with a National Senior Certificate entered Higher Education in 2009 and the Admission Point Score (APS) is calculated with values ranging from one to seven. The maximum value for the M-score is 30 (6 subjects x 5) and for the APS it is 49 (7 subjects x 7). Note that institutions do not uniformly apply the same weights to all subjects. For instance, at some universities Life Orientation is included when calculating the APS, whereas at other it is excluded. Table 3.3 provides the conversion scheme. It is repeated in this chapter as Table 5.5 to assist the reader.

**Table 5.5** ***Grade 12 results converted to a M-score(2006 to 2008) and an APS (2009)***
(Adapted from Websites of Wits, UCT, UP, UFS, UJ and SU)

| **% achieved** | **Symbol obtained** | **Until 2008 M-Score** | | **From 2009** APS score (NSC sc**ale of achievement)** |
|---|---|---|---|---|
| | | **HG** | **SG** | |
| **80 – 100** | A | 5 | 4 | 7 |
| **70 – 79** | B | 4 | 3 | 6 |
| **60 – 69** | C | 3 | 2 | 5 |
| **50 – 59** | D | 2 | 1 | 4 |
| **40 – 49** | E | 1 | 0 | 3 |
| **33 – 39** | F | 0.5 | 0 | 2 |
| **25 – 33** | G | 0 | 0 | 1 |

### 5.6.3 Scholastic proficiency

For the 2008 and 2009 cohorts the Stellenbosch University Access Test was employed as a measure of scholastic aptitude. The Access Test of the Stellenbosch University is a set of assessments developed by a group of specialists (academic and school teachers) at Stellenbosch University (Botha, du Plessis & Menkveld 2007:3-10). These tests were developed to evaluate prior knowledge and learning and allows for an examination of the correlation of this learning with academic outcomes. The Access Test consists of four sections namely: Mathematics, Physical Science, and Numeracy and Thinking skills.

The Access Test is included in this investigation because it provides a validated examination of scholastic proficiency independent from school performance. Originally developed in 1995, from 1998 to 2004 all applicants at Stellenbosch University with an aggregate average Grade 12-mark below 70% in Grade 11 or 12 had to complete the Access Test prior to admission (Botha *et al.* 2007:3-10). Since 2006, all applicants to Stellenbosch University had to write the Stellenbosch University Access Test. The Access Test results constitute 40% of the admission mark (with school results comprising the remaining 60%). Nel and Kistner (2009:953–973) demonstrated that the Access Test is a meaningful predictor of university performance and it accounted for explaining 36.2% of the variance in first-year performance for the whole Stellenbosch University (Nel 2009). According to Nel (2009), the final school results for 2009 (NSC) were on average 21% higher than the Access Test results. Nel and Kistner (2009:953–973) also pointed out that the proportion of variance of first-year performance that is explained by high school marks declined from 33% in 2001 to 26% in 2008 (Nel and Kistner 2009:953–973).

At Stellenbosch University the predictive value of university performance was determined within faculties (compared to the predictive value of Grade 12-results) from 2006 to 2009. Botha, Du Plessis, Kistner and Nel (2008:2) reported that in the Faculty of Science the Access Test raised the proportion of explained variance predictability to 44.8% (from 37.0%) and for Agricultural Sciences to 47.4% (from 44.1%). Interesting is the predictive value for other faculties such as Humanities (30.6% from 27.6%), Economical and Management Sciences (49.5% from 46.2%), Engineering (35.9% from 34.7%) and Health Sciences (41.3% from 36.7%). In conjunction with the Grade 12-results the Access Test results are therefore an important quantitative instrument for the Stellenbosch University.

In this study only the Mathematics and Physical Science tests from the Stellenbosch University were employed. Note that the results were used for research only and were not used for placement at the institution. The Stellenbosch University Mathematics test consists of 30 multiple choice items to be completed in 120 minutes. No electronic calculators are allowed. The items reflect a combination of routine, reasoning and multiple step questions. In Table 5.6, the theme and level of each item in the test are provided (Nel & Kistner 2008).

**Table 5.6** ***The SU Mathematics Access Test Themes and Levels***
(Adapted from SU Report, Nel & Kistner 2008)

| Theme | Level | Theme | Level |
|---|---|---|---|
| Exponents and surds | Routine | Presenting trig function | Reasoning |
| Solving equations | Routine | Coordinate geometry | Multiple step |
| Exponents and surds | Routine | Number patterns | Multiple step |
| Solving equations | Routine | Sequences and series | Multiple step |
| Algebraic manipulation | Multiple step | Inequalities | Multiple step |
| Logarithm | Routine | Inequalities; Convert between representation of functions | Multiple step; reasoning |
| Logarithm; function inverse | Multiple step | Convert between representation of functions | Routine |
| Exponents and surds | Routine | Properties of quadratic function | Multiple step |
| Solving simultaneous equations | Routine | Algebraic manipulation | Routine |
| Solving simultaneous equations | Reasoning | Relations | Reasoning |
| Pythagoras; geometry of polygon | Multiple step | Relations | Reasoning |
| Solving trig equations | Routine | Weighted average | Multiple step |
| Solving trig equations | Multiple step | Relations | Reasoning |
| Trigonometry; geometry of circles | Reasoning | 3D problem | Reasoning |
| Trigonometry | Reasoning | Interpreting graphs | Routine |

The Stellenbosch University Physical Science test consists of 17 Physics and 16 Chemistry items added together to present the total Physical Science score. The themes and levels of the items are given in Table 5.7.

**Table 5.7** ***The SU Physical Science Access Test Themes and Levels***
(Adapted from SU Report, Nel & Kistner 2008)

| Physics: Theme | Level | Chemistry: Theme | Level |
|---|---|---|---|
| Measurement | Routine | Ideal gas law | Cognitive |
| Data handling | Routine | Atomic structure | Routine |
| Motion (Acceleration) | Cognitive | pH | Routine |
| Motion (Velocity-time interpretation) | Cognitive | Molecular structure (Periodic table) | Routine |
| Velocity-time chart | Cognitive | Equilibrium | Routine |
| Net force | Cognitive | Redox reaction | Routine |
| Motion (Newton's 2nd Law) | Routine | Molecular structure | Routine |
| Motion (Newton's 3rd Law) | Routine | Reactions (H+ donor) | Routine |
| Motion (Free fall) | Routine | Atomic weights | Routine |
| Momentum | Routine | Concentration | Cognitive |
| Electrostatics | Routine | Atomic weights | Cognitive |
| Electrostatics (Coulomb's Law) | Routine | Molecular forces | Routine |
| Electric circuits | Routine | Stoichiometric calculations | Reasoning |
| Forces; Kinetic energy | Cognitive | Acid-base reaction | Routine |
| Electric circuits | Routine | Solubility | Routine |
| Electric circuits | Routine | Concentration; reaction | Routine |
| General | Reasoning | | |

Both tests (Mathematics and Physical Sciences) evaluate prior knowledge and skills and reflect scholastic proficiency in these three disciplines (i.e. Mathematics, Physics and Chemistry). The test is well-balanced with evenly distributed content and the level similar to the previous school leaving examination and would equally be suitable as a university entrance examination.

### 5.6.4 Non–cognitive predictors

Non-cognitive influences such as personality, affect and attitudes, are generally not suitable for inclusion as admission criteria but play an important role in understanding achievement and may be useful for placement. This study did not explore all the known non-cognitive influences but focused on personality traits and Mathematics study orientation.

#### *5.6.4.1 The Basic Traits Inventory (BTI)*

The Basic Traits Inventory (BTI) was developed by Taylor and De Bruin in 2002 (Taylor & De Bruin 2006) as a measure of personality traits. The authors endeavoured to ensure minimal bias across race, gender and language groups (Taylor & De Bruin 2006:2). The Basic Traits Inventory is a 193-item inventory that measures the so called Big Five personality factors: Extroversion, Neuroticism, Conscientiousness, Openness to Experience, and Agreeableness.

Items are responded to on a five-point Likert-type scale, with responses ranging from 'Strongly Agree' to 'Strongly Disagree' (cf. Section 4.3.5) (Ramsay, Taylor, De Bruin & Meiring 2008).

The BTI is included in this research because of its demonstrated validity within the South African context (Ramsay *et al*. 2008). Taylor and De Bruin (2006) reported the following reliability coefficients: Extroversion (0.87); Neuroticism (0.92); Openness to Experience (0.87); Agreeableness (0.89) and Conscientiousness (0.93) (cf. Figure 4.7). Factor analytic studies have supported the construct validity of the Basic Traits Inventory (Ramsay *et al*. 2008).

The participants in this study either completed the BTI as part of the Placement Battery of the institution or the test was administered with the Stellenbosch University Access Test during first-year orientation.

#### *5.6.4.2 Study Orientation in Mathematics Tertiary (SOMT)*

Study Orientation in Mathematics Tertiary (SOMT) is a questionnaire that measures a student's study orientation towards Mathematics (Maree, Prinsloo and Claassen 1997:36). The test comprises six fields, namely study attitude, Mathematics confidence or anxiety, information processing, study environment and study habits. There are 85 items and the participant responds on a five-point Likert-type scale, which ranges from rarely or never (0 to 15% of the time) to very often or always (86 to 100% of the time). Study orientation is determined by statements as "How often do you make careless mistakes in Mathematics?" or "How often do you panic when answering tests or examinations in Mathematics?"

Table 5.8 contains reliability coefficients for the six subscales as reported by Maree *et al*. (1997:36).

**Table 5.8** ***The SOMT Items and Reliability Coefficients***
(Adapted from Maree et al. 1997:34, Eiselen 2006:117)

| CONSTRUCTS | DESCRIPTION | RELIABILITY COEFFICIENT |
|---|---|---|
| Study attitude | The attitudes and beliefs related to Mathematical study | 0.728 – 0.800 |
| Mathematics confidence or anxiety | The extend that anxiety is experienced when engaged with Mathematics | 0.739 – 0.790 |
| Information processing | Study methods and strategies | 0.750 – 0.842 |
| Study environment | The extent of restriction the learning and study environment places on achievement | 0.713 – 0.765 |
| Study habits | The display of consistent and effective study approach in Mathematics | 0.786 – 0.790 |
| Problem-solving behaviour | The learning strategies (cognitive and non-cognitive) in Mathematics | 0.661 – 0.785 |

In this study only the SOMT total score was used for the data analysis. Maree led research that originally developed the instrument for senior phases of school but recently adapted the SOMT for use with first-year university students, with the assistance of Eiselen (2006:117). Maree *et al*. (1997:36) and Maree and Crafford (2005:88) illustrate the criterion validity for school learners as well as Engineering students Maree *et al*. (2003a:22).

### 5.6.5 Indicators of student success

Two sets of indicators of student success were used, namely (a) the classification of students into three success categories (i.e. pass, risk, and high risk) and (b) performance (expressed as a percentage) in individual fundamental Science modules. First, the classification of students into the three categories of success will be discussed.

#### *5.6.5.1 Global performance*

The performance of participants across three University of Johannesburg faculties (Science, Engineering & Health Science (Optometry) was examined. Only students who were registered for the minimum required number of modules per Faculty (i.e. four modules in Science and six modules each in Engineering and Optometry) were considered. Students were classified into three categories on the basis of number of modules passed: '*pass*'; '*risk*' or '*high risk*'. The categorisation proceeded according to the following rules:

- The status of '*pass*' was allocated to all students who passed at least 60% of their modules. These students were thus eligible to unconditionally continue their studies in the second semester.
- The status of '*risk*' was allocated to all students who passed less than 60%, but 50% or more of their modules. They conditionally continue with studies in the second semester depending on which modules (e.g. majors or electives) they passed.
- The status '*high risk*' was allocated to all students who failed more than 50% of their modules. These students could continue only with special permission from the dean.

This classification system accords with the academic regulations of the institute. The rationale underlying the use of these three categories was to try and discriminate between '*successful*' and '*less successful*' students. In order to adequately identify the co-determinants of a framework for student placement, the profile variables of those students who performed satisfactory (i.e. students with a '*pass*' status) were compared with the profile variables from those students who performed marginally satisfactory (i.e. students with a '*risk*' status) and finally, those who performed unsatisfactory (i.e. students with a '*high risk*' status).

A shortcoming of the study was the fact that the classification system did not distinguish between the various performance levels within the category '*pass*' or '*risk*'. Excellent academic achievement, an average '*pass*' and even marginal performance were all placed within the same '*pass*' category. This coarse categorisation was also applicable for students who failed all the modules and students who failed two of five modules. Refinement of the categories was however not possible given the classification and rules of the administration system of the university.

#### *5.6.5.2 Achievement in Fundamental Science modules*

For each of the three fundamental modules the final semester grades (expressed as a percentage) of students were captured. These grades reflect a combination of marks received for tests, practical assignments and sessions, tutorials, portfolios and a formal examination. Note that no final grades were captured for students who did not gain entry to the examination on the basis of poor performance during the semester. These students were excluded from analyses that focussed on performance in individual modules. Unsuccessful students were globally classified as '*high risk*' students and were included in the analyses that focussed on the global indicator of success.

## 5.7 STATISTICAL ANALYSIS

### 5.7.1 The independent variables: Labels and operational definitions

The independent variables include the biographical variables; school performance; scholastic aptitude and non-cognitive variables:

- **Biographical profile:** The biographical profile includes gender, age, ethnicity and home language.
- **School performance**: School performance was represented by the M-score (cohorts 2006 to 2008) and the APS score (cohort 2009).
- **Scholastic ability**: The prior learning and ability for learning were determined by using the Access Test results.
- **Non-cognitive attributes:** The non-cognitive influences on academic performance were measured with the BTI and SOMT.

### 5.7.2 The dependent variable: Labels and operational definition

The dependent variables were academic performance indicators in the first year. The performance was measured with final module results (based on overall first-year module achievement).

### 5.7.3 Description of Statistical Techniques

All analyses were carried out with SPSS. Firstly the relations between categorical biographical variables (e.g. gender, age, home language and ethnicity) and the three categories of student success were examined by means of the **Pearson chi-square test** of independence. A statistically significant ($p < 0.05$) chi-square will indicate a relationship between the biographical variable and student success.

The relations between performance in Grade 12 (M-score/APS) and the categories of student success were examined by means of one-way ANOVA's, where Grade 12-performance serves as the continuous variable and student success serves as the grouping variable. Where a significant $F$ was found ($p < 0.05$), **post hoc Scheffé** tests were used to identify which groups differed significantly from each other.

Thirdly, the non-parametric **Kruskal-Wallis one-way** test for independent groups was used to examine the relations between performance in individual Grade 12-subjects (i.e. English, Mathematics and Physical Science) and the three categories of student success. The Kruskal-Wallis test was used rather than the ANOVA because performance in Grade 12-subjects is expressed on an ordinal scale (1 to 5) rather than on a continuous linear scale. Where a statistical significance $H$-value was found ($p < 0.05$), pair-wise comparison tests were used to identify which groups differed significantly from each other.

Finally, to discriminate between groups at a level greater than chance, the **Wilks' lambda** test can be applied. The relations between performance on the Access Test and the performance in specific first-year modules were examined by means of hierarchical multiple regression analyses. In these analyses the aim was to examine whether the Access tests have predictive value above and beyond performance in Grade 12.

The order of entry of variables in the hierarchical analyses was as follows:
Step 1: Grade 12-performance; and
Step 2: Mathematics Access Test and Physical Science Access Test results.
At each step of the analysis a $R^2$-statistic was computed, which indicates the proportion of variance in the dependent variable that is explained by the independent variable(s) included at the step.

The difference between the $R^2$ at Step 1 and the $R^2$ at Step 2 indicates the amount of variance uniquely explained by the Access Tests, after taking into account the role of Grade 12-performance. A statistically significant ($p < 0.05$), change in $R^2$ from Step 1 to Step 2 signifies that the Access tests have predictive value over and above the Grade 12-performance.

Finally, the relations between personality and academic achievement were examined by means of the **multivariate analysis of variance**. Academic achievement status served as the grouping variable and BTI-scores as the continuous variable. The relations between the Study Orientation in Mathematics Tertiary (SOMT) performance and academic achievement were examined by means of the **univariate analysis of variance**. Academic achievement status served as the grouping variable and the total SOMT-score as the continuous variable.

Table 5.9 summarises the research objective with accompanying statistical analysis technique.

**Table 5.9** ***Statistical Techniques used in this Investigation***
(Adapted from Eiselen 2006:129)

| OBJECTIVE | STATISTICAL ANALYSIS | REFERENCE |
|---|---|---|
| Description of the sample | Frequencies of first year student intake | Table 5.1 |
| | Frequencies and percentages of descriptive statistics of the biographical data of first year students | Table 5.3 |
| | Frequencies and percentages of descriptive statistics of the distribution in academic programmes | Figure 5.3 |
| Determine academic success status | Establish the relationship between qualifications and success status using $\chi^2$ test of independence | Table 6.1 (whole sample)<br>Table 6.2 (per cohort) |
| Determine relation between gender and academic success | Establish the relationship between gender and success status using $\chi^2$ test of independence | Table 6.3 (whole sample)<br>Table 6.4 (per cohort) |
| Determine relation between age and academic success | Establish the relationship between age and success status using $\chi^2$ test of independence | Table 6.5 (whole sample)<br>Table 6.6 (per cohort) |
| Determine relation between home language and academic success | Establish the relationship between home language and success status using $\chi^2$ test of independence | Table 6.7 (whole sample)<br>Table 6.8 (per cohort) |
| Determine relation between ethnicity and academic success | Establish the relationship between ethnicity and success status using $\chi^2$ test of independence | Table 6.9 (whole sample)<br>Table 6.10 (per cohort) |
| Determine relation between general school result and academic success | Establish the relationship between Mean M-score /APS and success status using one-way ANOVA and post-hoc Scheffé tests. | Table 6.11 (per cohort) |

| | | |
|---|---|---|
| Determine relation between Grade 12 subject (English, Mathematics and Physical Science) results and academic success | Establish the relationship between Grade 12 subject (English, Mathematics and Physical Science) result and success status using one-way Kruskal-Wallis tests. | English: Table 6.12 (per cohort) Mathematics: Table 6.13 (per cohort) Physical Science: Table 6.14 (per cohort) |
| Determine relation between Access Test (Mathematics and Physical Science) and academic success | Establish the relationship between the Access Test results (Mathematics and Physical Science) and success status using one-way ANOVA and post-hoc Scheffé tests. | Mathematics: Table 6.15 (per cohort) Physical Science: Table 6.16 (per cohort) |
| Determine relation between Access Test, M-score / APS and Mathematics 1A performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Mathematics 1A performance using hierarchical multiple regression tests. | Table 6.17 + 6.18 (2008-cohort) Table 6.19+6.20 (2009-cohort) |
| Determine relation between Access Test, M-score / APS and Mathematics 1C performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Mathematics 1C performance using hierarchical multiple regression tests. | Table 6.21 + 6.22 (2008-cohort) Table 6.23+6.24 (2009-cohort) |
| Determine relation between Access Test, M-score / APS and Chemistry 1A performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Chemistry 1A performance using hierarchical multiple regression tests. | Table 6.25 + 6.26 (2008-cohort) Table 6.27+6.28 (2009-cohort) |
| Determine relation between Access Test, M-score / APS and Chemistry 1C performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Chemistry 1C performance using hierarchical multiple regression tests. | Table 6.29 + 6.30 (2008-cohort) Table 6.31+6.32 (2009-cohort) |
| Determine relation between Access Test, M-score / APS and Physics 1A performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Physics 1A performance using hierarchical multiple regression tests. | Table 6.33 + 6.34 (2008-cohort) Table 6.35+6.36 (2009-cohort) |
| Determine relation between Access Test, M-score / APS and Physics 1C performance | Establish the relationship between the Mathematics and Physical Science Access Test, M-score/APS and Physics 1C performance using hierarchical multiple regression tests. | Table 6.37 + 6.38 (2008-cohort) Table 6.39+6.40 (2009-cohort) |
| Determine relation between BTI factors and academic success | Establish the relationship between BTI factors and success status using multivariate analysis of variance and Wilks lambda tests. | Table 6.41 (per cohort) Table 6.42 (per cohort) Table 6.43 (per cohort) |
| Determine relation between SOMT factors and academic success | Establish the relationship between SOM factors and success status using univariate analysis of variance and Wilks lambda tests. | Table 6.44 (per cohort) |

Most of the above analysis will be reported in the next chapter.

## 5.8 ETHICAL CONSIDERATIONS

In this investigation the researcher strove to maintain objectivity and integrity and furthermore to employ professional judgement. The aspiration was to represent the area of expertise in an accurate and just way and report findings as comprehensively as possible. Details of theories, methods and research design are therefore disclosed to the best of the researchers' ability. Accountability towards society should also be considered (Mouton 2001:241-242). The obligation to conduct this research in a social responsive and responsible manner manifests in not keeping anything secret, to freely disseminate results and to be responsible to sponsors of this research.

Primary data (biographical and alternative tests) were collected during enrolment and orientation of students during the registration period at the beginning of the academic year. Confidentiality was maintained at all times and only the students providing written consent to use their information were included in this investigation. The secondary data (results of students) were obtained by the researcher, a permanent staff member in the Faculty of Science, by a signed declaration of a confidentiality clause. The Faculty of Science and other stakeholders within the university were kept fully informed on the progress and results of the study.

Participants were informed that the data obtained were to be used for research or diagnostic purposes. The latter was a secondary goal and would require students being interviewed and then referred for support. This research has not harmed anybody and results will be reported anonymously.

The researcher obtained permission from the University Research Committee to (a) use information provided on student application forms, (b) administer scholastic aptitude and tests and tests of relevant non-cognitive attributes, and (c) access the academic results of students as recorded on the university management information system. A "Memorandum of Non-Disclosure" was signed by the institution and Stellenbosch University to use the Stellenbosch University Access Tests. The agreement stipulated that none of the partners would disclose any results of any student or groups of students or publish any related information without formal consent from the other party. In order to ensure that the ethical criteria were satisfied, approval for the study was also obtained from the Ethics Committee of the University of Johannesburg. All the data were treated with the utmost confidentially.

## 5.9 SYNTHESIS

This chapter introduces the research method and commences to contextualize the importance of this chapter in this study. It is explained that the research design centres on the purpose of the research and that the research aim and objectives steered the process in the investigation and measurement with the use of statistical concepts, procedures and analyses.

The main research purpose focuses on the possibility to establish a framework for the placement of university students, in Science programmes, for optimal academic success. The subsidiary research objectives are formulated and relate to students school performance (total Grade 12-score and Grade 12 Mathematics, Physical Science and English results); the Access Test battery from Stellenbosch University (as additional indicator) and personality traits to act as predictors of success in first-year Higher Education in Science modules. It is also explained that an exploration of the predictor-variables was identified empirically which might assist with strategies to increase the throughput rates of undergraduate students in Science programmes.

The next chapter discusses the statistical correlations between Grade 12-results and the contribution of the Access Test with Mathematics, Chemistry and Physics achievement at first-year level. The limitations of this investigation are discussed in chapter eight which focuses on further recommendations and conclusions.

# CHAPTER 6

## *RESULTS*

## 6.1 INTRODUCTION

In this chapter the results of the empirical investigation are reported in accordance with the following sub-themes:

- The relationship(s) between academic achievement and field of study.
- The relationship(s) between biographical variables (gender, age, home language and ethnicity) and academic achievement.
- The relationship(s) between cognitive variables and academic achievement with specific reference to:
  - school results (total Grade 12-score, as well as selected subject marks) and
  - alternative access test results and aptitude in Mathematics and Science.
- The relationship(s) between personality and attitude towards Mathematics and academic achievement.

Figure 6.1 below is a graphic illustration of the route through this chapter.

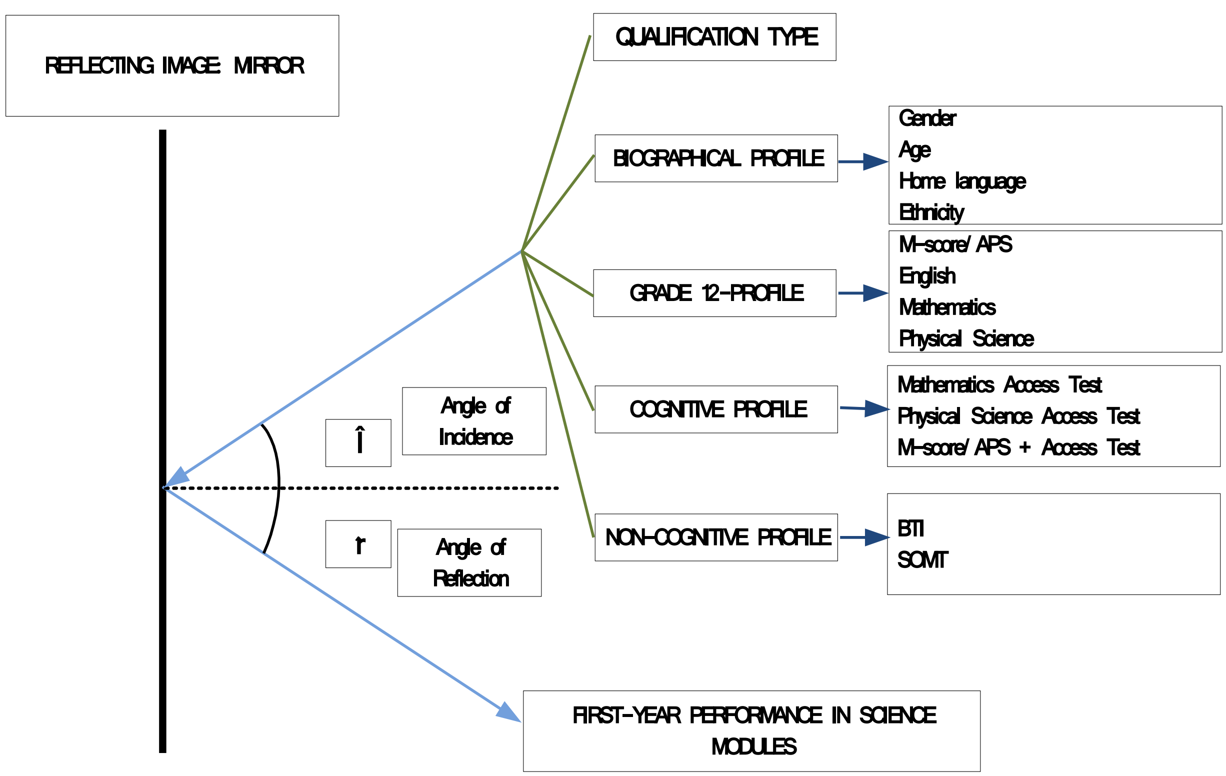


***Figure 6.1*** **The empirical components of the study**

The diagram presents the metaphor of a mirror, with incident 'light rays' reflected by the mirror. The five 'incident rays' represent the five broad empirical components investigated in this study, namely: field of study, biographical profile, Grade 12-profile, cognitive profile and non-cognitive profile. These five aspects are converged (cf. Figures 2.4 and 3.4) by a convex lens to a single incident ray projected on the mirror. The mirror reflects incident light and the reflected 'light ray' represents academic achievement in the first-year. The assumption underlying this figure is that all these components have an influence on academic achievement.

## 6.2 RELATIONS BETWEEN ACADEMIC ACHIEVEMENT AND FIELD OF STUDY

### 6.2.1 Introduction

This section examines the relations between field of study and academic achievement. A comparison of academic achievement in the three fields of study (Science, Engineering and Optometry) is necessary, because the Engineering and Optometry students follow a first-year curriculum of almost pure fundamental Science modules and all three groups register for the fundamental modules of Mathematics, Physics and Chemistry.

Academic achievement is operationalised in two ways, namely (a) an ordered categorical representation of academic status after the first semester of the first-year ('*pass*', '*risk*', '*high risk*'), and (b) as actual marks (expressed as a percentage) obtained in Mathematics, Physics and Chemistry modules in the first semester of the first-year.

### 6.2.2 Academic achievement in Science programmes

Students in Science programmes may enrol for any of four different programmes, namely: Mathematical Sciences, Physical Sciences, Life and Environmental Sciences and Information Technology. These students register for a minimum of eight modules in the first semester and have to pass at least five of these in order to be classified with a '*pass*' status. Students who pass a maximum of four of the eight modules are classified with a '*risk'* status. Students who pass less than four of the eight modules are classified with a '*high risk'* status. In Table 6.1 below, the academic status of the participating first-year students in the Faculty of Science (degree programmes) are compared across the four cohorts (2006 to 2009).

**Table 6.1** ***Academic Achievement in Science Degree Programmes (2006 to 2009)***

| Cohort | | Academic Status | | | Total |
|---|---|---|---|---|---|
| | | Pass | Risk | High risk | |
| 2006 | *N* | 407 | 102 | 115 | 624 |
| | % | 65.2 | 16.3 | 18.4 | 100.0 |
| 2007 | *N* | 334 | 46 | 135 | 515 |
| | % | 64.9 | 8.9 | 26.2 | 100.0 |
| 2008 | *N* | 149 | 39 | 29 | 217 |
| | % | 68.7 | 18.0 | 13.4 | 100.0 |
| 2009 | *N* | 262 | 197 | 255 | 714 |
| | % | 36.7 | 27.6 | 35.7 | 100.0 |
| TOTAL | *N* | 1152 | 384 | 534 | 2070 |
| | % | 55.7 | 18.6 | 25.8 | 100.0 |

The successful ('*pass*') category represents approximately two-thirds of the Science students' in the 2006, 2007 and 2008 cohorts. The 2009 cohort is an exception, with a relatively low proportion of students in the '*pass*' category (36.7%) and a relatively high proportion of students in the '*high risk*' category (35.7%). Across the four cohorts the proportion of students in the '*pass*' category is 55.7%, but this proportion is biased downward due to the relatively large size of the 2009 cohort (almost equal in size to the 2007 and 2008 cohorts combined). Similarly, the proportion of students in the '*high risk*' category across the four cohorts (25.8%) is biased upward due to the heavily weighted influence of the 2009 cohort.

### 6.2.3 Academic status in Engineering degree programmes

Students in Engineering may enrol in any of three different programmes, namely Civil, Mechanical, and Electrical and Electronic Engineering. Students register for 11 modules in the first-year, with six and five modules in the first and second semesters, respectively. Engineering students have to pass four of the six modules of the first semester to be classified with a *'pass'* status. Students who passed a maximum of three modules are classified with a '*risk*' academic status. Students who passed less than three of the six modules are classified with a '*high risk*' academic status.

In Table 6.2 the status of the students in the Engineering programmes is compared across three cohorts (2006 to 2008). No Engineering students participated in this research in 2009.

**Table 6.2** ***Academic Achievement in Engineering Degree Programmes (2006 to 2008)***

| Cohort | | Status | | | Total |
|---|---|---|---|---|---|
| | | Pass | Risk | High risk | |
| 2006 | *N* | 100 | 16 | 25 | 141 |
| | % | 70.9 | 11.3 | 17.7 | 100.0 |
| 2007 | *N* | 60 | 7 | 39 | 106 |
| | % | 56.6 | 6.6 | 36.8 | 100.0 |
| 2008 | *N* | 68 | 20 | 16 | 104 |
| | % | 65.4 | 19.2 | 15.4 | 100.0 |
| TOTAL | *N* | 228 | 43 | 80 | 351 |
| | % | 64.9 | 12.2 | 22.8 | 100.0 |

The academic successful (‘*pass*’) category consistently represents about two-thirds of the Engineering students. The 2007 cohort is an exception, with just more than 56% of the students being successful.

### 6.2.4 Academic status in Optometry degree programme

Students in Optometry programme register for six modules in the first semester and similar criteria as above are applied to categorise academic achievement. The Optometry students who passed four of the six modules of the first semester are awarded a *‘pass’* status. The students who passed at least three of the six modules are classified with a ‘*risk*’ academic status. Students passing less than three of the six modules are classified as students with a ‘*high risk*’ academic status.

**Table 6.3** ***Academic Achievement in Optometry Degree Programme (2006 to 2009)***

| Cohort | | Status | | | Total |
|---|---|---|---|---|---|
| | | Pass | Risk | High risk | |
| 2006 | *N* | 7 | 1 | 0 | 8 |
| | % | 87.5 | 12.5 | .0 | 100.0 |
| 2007 | *N* | 7 | 0 | 0 | 7 |
| | % | 100.0 | .0 | .0 | 100.0 |
| 2008 | *N* | 31 | 9 | 3 | 43 |
| | % | 72.1 | 20.9 | 7.0 | 100.0 |
| 2009 | *N* | 1 | 0 | 0 | 1 |
| | % | 100.0 | .0 | .0 | 100.0 |
| TOTAL | *N* | 46 | 10 | 3 | 59 |
| | % | 78.0 | 17.0 | 5.0 | 100.0 |

Tables 6.1 to 6.3 show that low numbers of Optometry students participated relative to Sciences and Engineering students. The academic successful (‘*pass*’) category represents almost 80% of the Optometry students, which may reflect the strict selection criteria that applies to this

programme. The programme allows for enrolment of up to 40 students per year and there are more than 200 applications received annually.

### 6.2.5 Academic status in the total group of participants

Table 6.4 summarises the first-year achievement across the different cohorts in each field of study. Note that the total pool of participants was constituted by 83% Science students, 14% Engineering students and 3% Optometry students.

Across the four cohorts, 78.0% of the Optometry students were successful, in comparison to the 64.9% of Engineering students and 55.7% of the Science students. The Pearson chi-square test of independence showed a statistically significant relation between field of study and student success across the four cohorts ($\chi^2 = 26.305$; $df = 2$, $p = 0.001$). Comparison of the percentages in Table 6.4 across the fields of study shows that relatively similar proportions of Science and Engineering students were placed in the three categories of academic achievement, but in Optometry a noticeably greater proportion was placed in the *'pass'* category and a smaller proportion was placed in the '*high risk*' category. The results show that the field of study plays a statistically significant role in explaining academic achievement in fundamental Science modules. Note that approximately 25% of Science and Engineering students fall in the '*high risk*' category, whereas only 5% of Optometry students fall in this category.

**Table 6.4** ***Academic Achievement in Three Fields of Studies (2006 to 2009)***

| Field of study | | Status | | | |
|---|---|---|---|---|---|
| | | Pass | Risk | High risk | Total |
| Science | *N* | 1152 | 384 | 534 | 2070 |
| | % | 55.7 | 18.5 | 25.8 | 100.0 |
| Engineering | *N* | 228 | 43 | 80 | 351 |
| | % | 64.9 | 12.2 | 22.8 | 100.0 |
| Health Sciences | *N* | 46 | 10 | 3 | 59 |
| (Optometry) | % | 78.0 | 17.0 | 5.0 | 100.0 |
| Total | *N* | 1426 | 437 | 617 | 2480 |
| | % | 57.5 | 17.6 | 24.9 | 100.0 |

## 6.3 THE RELATIONS BETWEEN ACADEMIC ACHIEVEMENT AND BIOGRAPHICAL VARIABLES

This investigation is probing four biographical variables. In the section that follows the relations of academic achievement with gender, age, home language and ethnicity are given.

### 6.3.1 The relationship between academic achievement and gender

Table 6.5 shows the relationship between gender and academic achievement across the four cohorts of students and fields of study combined.

The sample consisted of approximately 59% female and 41% males. Visual inspection of Table 6.5 indicates that the proportions of male and female students across the three categories of success are similar. This is confirmed by the Pearson chi-square test of independence for the total group of participants ($\chi^2$ = 0.932, *df* = 2, *p* = 0.628). Across the four cohorts, gender does not appear to play a meaningful role in explaining academic achievement. This finding contradicts conventional wisdom that males perform better in Engineering and Sciences due to stronger mechanical and practical abilities.

**Table 6.5** ***Relationship of Gender with Academic Achievement***

| Cohort | Gender | | Status | | | Total |
|---|---|---|---|---|---|---|
| | | | Pass | Risk | High risk | |
| 2006-2009 | Male | *N* | 570 | 186 | 250 | 1006 |
| | | % | 56.7 | 18.5 | 24.9 | 100.0 |
| | Female | *N* | 856 | 251 | 367 | 1474 |
| | | % | 58.1 | 17.0 | 24.9 | 100.0 |
| | Total | *N* | 1426 | 437 | 617 | 2480 |
| | | % | 57.5 | 17.6 | 24.9 | 100.0 |

### 6.3.2 The relationship between academic achievement and age

The participants are grouped into three age categories, namely students between 17 and 19 years were placed in '19 and younger' category. Students who were 20 or 21 years were placed in the '20 or 21' category, whereas all students of 22 years or older were placed in the '22 and older' category. Table 6.6 reflects the relationship between age and academic achievement.

**Table 6.6** ***Relationship between Student Age and Academic Achievement***

| Cohort | Age (years) | | Status | | | Total |
|---|---|---|---|---|---|---|
| | | | Pass | Risk | High risk | |
| 2006-2009 | 19 or younger | *N* | 621 | 245 | 339 | 1205 |
| | | % | 51.5 | 20.3 | 28.1 | 100.0 |
| | 20 to 21 | *N* | 532 | 117 | 181 | 830 |
| | | % | 64.1 | 14.1 | 21.8 | 100.0 |
| | 22 or older | *N* | 140 | 27 | 56 | 223 |
| | | % | 62.8 | 12.1 | 25.1 | 100.0 |
| | Total | *N* | 1293 | 389 | 576 | 2258 |
| | | % | 57.3 | 17.2 | 25.5 | 100.0 |

The sample consisted of 54% students who were 19 years or younger, 29% who were either 20 or 21 years old, and 17% who were 22 years or older. The Pearson chi-square test of independence revealed that the relationship between age and academic achievement was statistically significant ($\chi^2 = 45.703; df = 2; p < 0.001$). Proportionally, students in the '20 to 21' category and the '22 or older' category were similarly distributed across the three categories of achievement. Relatively fewer students in the '19 or younger' category were placed in the '*pass*' category, and relatively more of these students were placed in the '*high risk*' category. This result indicates that younger students are at a greater risk of failing than older students are.

### 6.3.3 Relation of academic achievement and home language

There are four home language categories for the placement of participants, namely English, indigenous African, Afrikaans and 'Other'. Table 6.7 shows the relationship between home language and the categories of academic achievement.

**Table 6.7** ***Relationship between Home Language and Academic Achievement***

| Cohort | Home language | | Status | | | Total |
|---|---|---|---|---|---|---|
| | | | Pass | Risk | High risk | |
| 2006-2009 | English | *N* | 435 | 105 | 124 | 664 |
| | | % | 65.5 | 15.8 | 18.7 | 100.0 |
| | Indigenous African | *N* | 597 | 239 | 387 | 1223 |
| | | % | 48.8 | 19.5 | 31.7 | 100.0 |
| | Afrikaans | *N* | 346 | 77 | 88 | 511 |
| | | % | 67.7 | 15.1 | 17.2 | 100.0 |
| | Other | *N* | 48 | 16 | 18 | 82 |
| | | % | 58.5 | 19.5 | 22.0 | 100.0 |
| | Total | *N* | 1426 | 437 | 617 | 2480 |
| | | % | 57.5 | 17.6 | 24.9 | 100.0 |

The sample consisted of approximately 49% students with an Indigenous African home language, 27% with English as home language, 21% with Afrikaans as home language, and 3% with another home language. The Pearson chi-square test of independence revealed a statistically significant relation between home language and academic achievement ($\chi^2 = 84.116$, $df = 6$, $p < 0.001$). Visual inspection of Table 6.7 shows that relative to the other language groups, a proportionally large number (approximately 32%) of indigenous African home language students were placed in the '*high risk*' category. In addition, relative to the other language groups, a proportionally small number of indigenous African home language (approximately 49%) students were placed in the '*pass*' category. The results indicate that the English and Afrikaans home language students performed very similar with more than 65% in the *'pass'* category. Overall, the results show that students with an indigenous African home language are at a greater risk to fail, than students with Afrikaans, or English as home language are.

### 6.3.4 The relationship between academic achievement and ethnicity

There are four ethnic categories for placement of the participants, namely Black, Coloured, White and Indian. The university uses these categories for administrative purposes and accords with the ethnic categories used by the South African government. Inequalities with respect to the distribution of social, economic, and educational resources continue to exist between these groups. Against this background, it remains relevant to examine differences in academic achievement between these groups as such differences serve to highlight the inequalities and the effects thereof and emphasise the need for corrective measures.

Table 6.8 shows the relationship between ethnicity and the categories of academic achievement.

**Table 6.8** ***Relationship between Ethnicity and Academic Achievement***

| Cohort | Ethnic group | | Status | | | Total |
|---|---|---|---|---|---|---|
| | | | Pass | Risk | High risk | |
| 2006-2009 | Black | *N* | 667 | 266 | 420 | 1353 |
| | | % | 49.3 | 19.7 | 31.0 | 100.0 |
| | Coloured | *N* | 41 | 8 | 15 | 64 |
| | | % | 64.1 | 12.5 | 23.4 | 100.0 |
| | White | *N* | 652 | 138 | 160 | 950 |
| | | % | 68.6 | 14.5 | 16.9 | 100.0 |
| | Indian | *N* | 66 | 25 | 22 | 113 |
| | | % | 58.4 | 22.1 | 19.5 | 100.0 |
| | Total | *N* | 1426 | 437 | 617 | 2480 |
| | | % | 57.5 | 17.6 | 24.9 | 100.0 |

The sample consisted of approximately 55% Black students, 38% White students, 5% Indian students, and 3% Coloured students. The Pearson chi-square test of independence revealed that the relationship between ethnicity and academic achievement was statistically significant ($\chi^2 = 94.110$, $df = 6$, $p < 0.001$).

Visual inspection of Table 6.8 shows that relative to the other groups, a proportionally large number (approximately 31%) of Black students were placed in the '*high risk*' category. In addition, relative to the other language groups, a proportionally small number of Black students (approximately 49%) were placed in the '*pass*' category. The achievement of the Coloured and Indian groups fell between that of the White and Black groups. Note that the Coloured and Indian groups consisted of relatively small numbers of participants and the observed proportions may be less stable than those observed for the White and Black groups. Furthermore, the observed proportions for the Black and White groups mirror those observed for the indigenous

African on the one hand, and the English and Afrikaans groups on the other hand (compare Table 6.7).

### 6.3.5 The relationship between academic achievement and biographical variables

Comparing the four cohorts according to gender, age, home-language and ethnicity indicates that *gender* holds no relevance to academic achievement in fundamental Science modules in the first-year at university (cf. Section 6.3.2). However, the other variables present noteworthy results. Results indicate that as a whole, older students perform better than younger students do (Section 6.3.2).

Analysis of the relation between home language and academic achievement yielded an important result. The faculties where data were collected have English as the language of tuition. Students with English and Afrikaans as home language performed well relative to students with an indigenous African language as their home language. Less than 50% of students with an indigenous African language as home language were placed in the '*pass*' category. Of the remaining students in this group, 19% were placed in the '*risk*' category and 32% in the '*high risk*' category. The unsatisfactory performance of the African language students relative to that of the Afrikaans and English students might be attributed to a multitude of factors, including unequal access to educational, economic, social, and health resources. After 16 years of democracy it remains true that township schools (where children with an African home language are most likely to be schooled) are weaker equipped with respect to facilities, teachers, and educational resources (cf. Section 3.4.1.3). Against this background, it should come as no surprise that African language students perform weaker than their English does and Afrikaans counterparts should. However, the poor performance of the African language students remain a source of concern and calls for continued intervention from educational experts and researchers.

The charts in figure 7.2 (below) present the distribution of students with respect to academic status across the four home language groups. The distribution of the '*pass*' category from 49% to 68% can be visually inspected in the green sectors with the indigenous African home language group having the lowest representation in the '*pass*' category. The relatively high frequency of students in the '*high risk*' category (in red) from 17% (Afrikaans) to 32% (indigenous African) is of concern. The indigenous African home language group has proportionally high representation in the '*risk*' and '*high risk*' indicating that this home language factor is a non-negligible indicator of academic achievement.

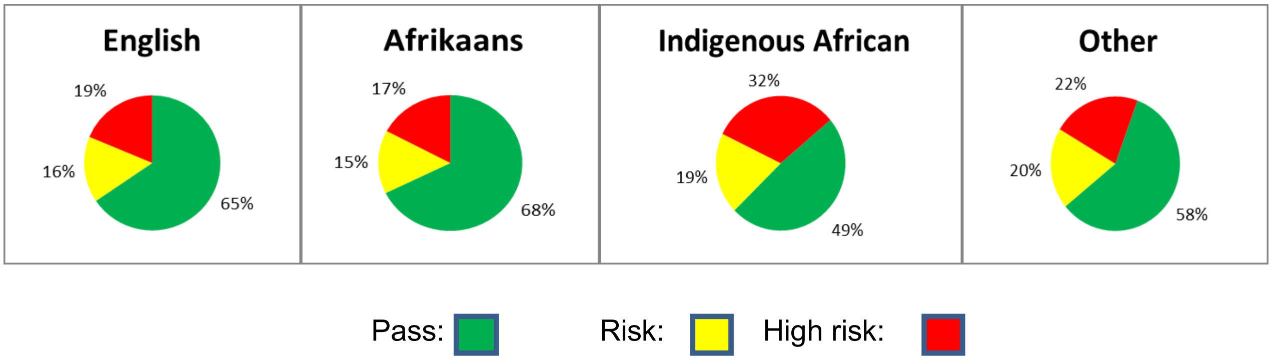


***Figure 6.2*** **Relation between home language and academic achievement**

Corresponding to the home language result is the relation of *ethnicity* and academic achievement. Fewer than 20% of White and Indian students fell in the '*high risk*' category (red sector). Black and Coloured ethnic groups however had between 20% to 31% representation in the '*high risk*' category (Section 6.3.4). The distribution of the '*pass*' category from 49% to 69% can be visually inspected in the green sectors and corresponds with the home language grouping found above (cf. Figure 6.3). The highest representation in the '*high risk*' category (red sector) is the Black ethnic group (with 31%) and as stated above indicates that ethnicity together with home language should be regarded as important indicators of academic achievement.

In figure 6.3, the charts present the representation of the four ethnic groups.

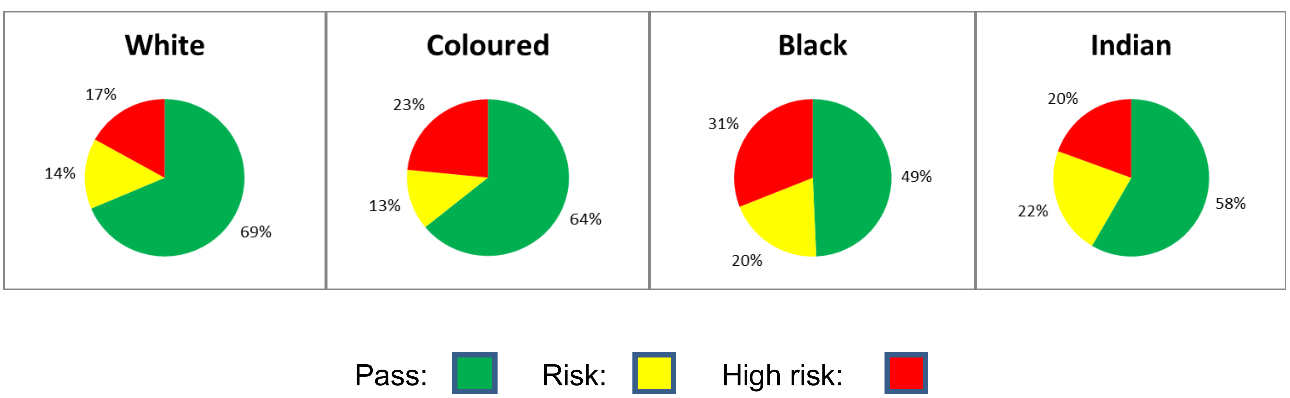


***Figure 6.3*** **Relation between ethnicity and academic achievement**

Universities should be prepared to respond to the language and cultural diversity of first-year students. Institutions expect students to transform and then the universities remain unchanged. Above results are evident of the transformation required by institutions to adapt to student needs when they enter the new environment.

## 6.4 THE RELATIONS BETWEEN ACADEMIC ACHIEVEMENT OF FIRST-YEAR UNIVERSITY STUDENTS AND SCHOOL ACHIEVEMENT

This section focuses on the relations of achievement in the first year with three indicators of school achievement, namely:

i) M-score (for the 2006, 2007, and 2008 cohorts),

ii) APS (for the 2009 cohort), and

iii) achievement in English, Mathematics, and Physical Science as individual school subjects.

### 6.4.1 The relationship of Grade 12-profile (M-Score and APS) with academic achievement

In Table 5.5, the table presents the conversion for school achievement to the M-score and APS. Table 6.9 presents the comparison of the M-Score or APS across the three categories of university achievement in each of the four different cohorts.

Inspection of Table 6.9 shows that in each of the four cohorts, students in the '*pass*' category performed better in Grade 12, than students in the '*risk*' and '*high risk*' categories. Similarly, students in the '*risk*' category, performed better in Grade 12 than the *'high risk'* group. A one way ANOVA across the four cohorts reveal a statistically significant relationship between overall Grade 12-achievement and university achievement (cf. Section 5.7.3). Note the differences in means between the three categories of students were small, proposing that the statistically significant relationship is relatively weak in a practical sense.

**Table 6.9** ***Mean M-score (2006 to 2008 Cohorts) & APS score (2009 Cohort) and Academic Achievement***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| 2006 (M-Score) | 19.34 | 5.35 | 18.39 | 5.70 | 18.12 | 5.26 |
| 2007 (M-Score) | 19.27 | 4.87 | 19.22 | 4.94 | 17.69 | 4.73 |
| 2008 (M-Score) | 19.84 | 4.50 | 19.11 | 4.00 | 17.81 | 3.61 |
| Total (M-score) | 19.48 | 4.25 | 18.91 | 4.63 | 17.89 | 4.48 |
| 2009 (APS) | 31.16 | 8.29 | 29.06 | 9.19 | 28.04 | 10.72 |

For the **2006** cohort, the means of the '*pass*', '*risk*' and '*high risk*' categories did not differ significantly [$F$ = 2.735; $df$ = 2,175; $p$ = 0.056]. However, for the **2007** cohort, $F$ = 2.896; $df$ =

2,521; $p$ = 0.007. Post hoc Scheffé tests showed the mean M-scores of the *'pass'* students and the '*high risk*' students were significantly different ($p$ = 0.008). Note that from a practical perspective the difference in means was less than the difference between the two M-score points. Given a standard deviation of approximately five M-score points and given that M-scores can range between 6 and 30, a difference of less than two M-score points (less than half of a standard deviation) is small from a practical perspective.

For the **2008** cohort, $F$ = 4.636; $df$ = 2,345; $p$ = 0.010. Post hoc Scheffé tests showed that the mean M-scores of the '*pass*' students and the '*high risk*' students were significantly different ($p$ = 0.013). For the **2009** cohort, $F$ = 3.170; $df$ = 2,300; $p$ = 0.046. The Post hoc Scheffé tests showed the mean APS scores of the '*pass*' students and the '*high risk*' students were non-significantly different ($p$ = 0.052) (compare Table 6.9). However, the observed $p$ value was close to significance.

### 6.4.2 The relationship of Grade 12 English with academic achievement

The Grade 12-results (M-score and APS) provide a quantitative measure to express the achievement in all the Grade 12-subjects taken together. Subsequently, a comparison of the Grade 12-result for English to academic achievement at university is drawn. For the 2006 to 2008 cohorts achievement is expressed on a five point-scale (A symbol = 5 points, B symbol = 4 points, C symbol = 3 points, D symbol = 2 points, E symbol = 1 point). For students who passed English on the Standard Grade in the 2006, 2007 and 2008 cohorts' there is a one point deduction.

For the 2009 cohort the achievement is expressed on a seven point-scale (80% to 100% = 7 points, 70% to 79% = 6 points, 60% to 69% = 5 points, 50% to 59% = 4 points, 40% to 49% = 3 points, 33% to 39% = 2 points and 25% to 32% = 1 point). There is no provision for Standard Grade in the NSC.

Table 6.10 shows student achievement in Grade 12 English across the three categories in each of the four cohorts.

**Table 6.10** ***Grade 12 English Results across Cohorts and Academic Achievement categories***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| 2006 | 3.41 | 1.10 | 2.92 | 1.16 | 3.12 | 0.99 |
| 2007 | 3.24 | 1.05 | 2.97 | 1.06 | 2.84 | 1.03 |
| 2008 | 3.36 | 1.07 | 3.29 | 1.11 | 3.09 | 0.95 |
| 2009 | 4.32 | 1.04 | 4.26 | 1.07 | 4.15 | 1.08 |

For the 2006, 2007, and 2008 cohorts, scores for English range from one to five, whereas for the 2009 cohort scores range from one to seven. The best description for these scores is ordinal scores. Against this background, the Kruskal-Wallis test as a non-parametric alternative for the standard one-way ANOVA, is used.

One-way Kruskal-Wallis tests across the four cohorts revealed a statistically significant (but small) difference in the overall Grade 12 English results and the three categories of university achievement. For the **2006** cohort, $H = 11.785$; $df = 2$; $p = 0.003$, and pairwise comparison tests showed that the '*pass*' students performed statistically significantly better than the '*risk*' students (compare Table 6.10). It is noteworthy (and unexpected) that the "*high-risk*" students had better Grade 12 English results (M = 3.12) than the '*risk*' category (M = 2.92). For the **2007** cohort, $H = 9.253$; $df = 2$; $p = 0.010$, and pairwise comparison tests showed that the '*pass*' students performed significantly better than the '*risk*' students and the '*risk*' students better than the '*high risk*' students.

For the **2008** cohort, $H = 2.905$; $df = 2$; $p = 0.234$, as well as the **2009** cohort, $H = 4.024$; $df = 2$; $p = 0.134$, non-significant relationships between English at Grade 12-level and academic achievement was observed. A trend where better achievement in English is associated with better achievement at university is observed.

### 6.4.3 The relationship of Grade 12-profile (Mathematics results) with academic achievement

A conversion of Grade 12-results in Mathematics, in the same way as the results for Grade 12 English, is performed. Table 6.11 summarises student achievement in Grade 12 Mathematics across the three achievement categories in each of the four cohorts.

Kruskal-Wallis tests across the four cohorts revealed a statistically significant relationship between overall Grade 12-achievement and university achievement per cohort. For the **2006** cohort, $H = 15.426$; $df = 2$; $p = 0.001$, and pairwise comparison tests showed that the '*pass*' students performed significantly better than the '*risk*' students (compare Table 6.11). The fact that the '*high risk*' students (M = 2.26) performed better than the '*risk*' students (M = 2.18) is unexpected.

**Table 6.11** ***Grade 12 Mathematics Results across Cohorts and Academic Achievement Categories***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| 2006 | 2.67 | 1.41 | 2.18 | 1.26 | 2.26 | 1.23 |
| 2007 | 2.57 | 1.37 | 2.78 | 1.42 | 3.08 | 1.29 |
| 2008 | 3.11 | 1.19 | 3.09 | 1.07 | 2.62 | 1.13 |
| 2009 | 4.97 | 1.54 | 4.77 | 1.61 | 4.60 | 1.60 |

For the **2008** cohort, $H$ = 6.208; $df$ = 2; $p$ = 0.045, as well as the **2009** cohort, $H$ = 8.800; $df$ = 2; $p$ = 0.012, statistically significant relationships between Grade 12 Mathematics level and academic achievement was observed. However, for the **2007** cohort, $H$ = 1.770; $df$ = 2; $p$ = 0.413, and pairwise comparison tests shows that the '*high risk*' students performed better than the '*pass*' and '*risk*' student categories. This result is unexpected.

### 6.4.4 The relationship of Grade 12 (Physical Science results) with academic achievement

The Grade 12 Physical Science results are converted in the same way as the results for Grade 12 English and Mathematics. Table 6.12 summarises student achievement in Grade 12 Physical Science across the three categories in each of the four cohorts.

**Table 6.12** ***Grade 12 Physical Science Results across Cohorts and Academic Achievement Categories***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| 2006 | 2.46 | 1.35 | 2.14 | 1.25 | 2.34 | 1.30 |
| 2007 | 2.42 | 1.26 | 2.41 | 1.24 | 2.36 | 1.28 |
| 2008 | 2.77 | 1.08 | 2.62 | 0.99 | 2.39 | 1.07 |
| 2009 | 3.95 | 2.05 | 3.78 | 1.25 | 3.65 | 1.26 |

Kruskal-Wallis tests across the four cohorts revealed a statistically significant relationship between overall Grade 12-achievement and university achievement per cohort. For the **2006** cohort, $H$ = 4.9265; $df$ = 2; $p$ = 0.085, and pairwise comparison tests showed that the 'pass' students (M = 2.46) performed significantly better than the '*risk*' students (compare Table 6.12). The fact that the '*high risk*' students (M = 2.34) performed better than the '*risk*' students (M = 2.14) is unexpected. For the **2007** cohort, $H$ = 0.145; $df$ = 2; $p$ = 0.930 and pairwise comparison tests showed that the '*pass*' students performed significantly better than the '*risk*' students (M = 2.41) and the '*high risk*' students (M = 2.36) (compare Table 6.12) as expected.

For the **2008** cohort, *H* = 4.226; *df* = 2; *p* = 0.121 and pairwise comparison tests showed that the '*pass*' students (M = 2.77) performed significantly better than the '*risk*' students (compare Table 6.12). The fact that the '*risk*' students (M = 2.62) performed better than the '*high risk*' students (M = 2.39) is also expected. For the **2009** cohort, *H* = 7.175; *df* = 2; *p* = 0.028, and pairwise comparison tests showed that the '*pass*' students (M = 3.95) performed significantly better than the '*risk*' students (compare Table 6.12). The fact that the '*risk*' students (M = 3.78) performed better than the '*high risk*' students (M = 3.65) is also expected.

### 6.4.5 The relationship between academic achievement and Grade 12-results

Overall Grade 12-achievement and achievement in English, Mathematics and Physical Science contributed to the compilation of a profile of successful first-year students in Science and related programmes. The results show a pattern in which better achievement in Grade 12 is associated with better achievement at university. The observed relations are not particularly strong and it is clear that high school achievement (as reflected in school results) is not to be viewed as a flawless predictor of university achievement.

One important advantage of the use of school achievement as predictor of university achievement is that school achievement indicators are available at little or no cost prior to registration. The above variables (Grade 12 English, Mathematics and Physical Sciences) seem to be appropriate to apply within admission and registration of students. Institutions would then admit students based only on results achieved after the final school assessment. If the universities had more information available to profile the individual student, informed decisions would be possible. With more time provided, careful analysis of the variables could be applied to provide the student with useful information. A comparison of the specific student profile to the profile of successful students (in a similar programme) would propose appropriate placement into one or even a few programmes. Placement opportunities in suitable programmes/modules would provide students with information and enable making decisions based on personal abilities, proficiency and preferences.

## 6.5 THE RELATION BETWEEN ACADEMIC ACHIEVEMENT OF FIRST-YEAR UNIVERSITY STUDENTS AND MEASURED PROFICIENCY IN MATHEMATICS AND PHYSICAL SCIENCE

This section focuses on the relations of standardised indicators of academic aptitude in Mathematics and Physical Sciences with academic achievement at university. Two cohorts of students, namely the 2008 and 2009 cohorts, completed the Stellenbosch University Mathematics and Physical Science Access Tests (cf. Section 5.6.3).

The relations between the Access Tests and school proficiency are analysed with one-way analyses of variance (ANOVA) in order to determine statistically significance of academic achievement at first-year level.

### 6.5.1 The relation of the SU Mathematics Access Test scores with academic achievement

Table 6.13 compares mean Mathematics Access Test scores across the three categories of achievement in each of the two different cohorts.

**Table 6.13** ***Mean Mathematics Access Test Scores across Academic Achievement Categories***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| Total | 34.15 | 15.41 | 30.72 | 12.34 | 30.53 | 12.84 |
| 2008 (n = 286) | 36.17 | 16.51 | 34.27 | 15.76 | 35.98 | 15.54 |
| 2009 (n = 234) | 30.31 | 12.24 | 28.61 | 9.23 | 28.76 | 11.37 |

For the **2008** cohort, $F = 0.275$; $df = 2{,}283$; $p = 0.760$ which shows that the mean scores of the three groups of students do not differ significantly. Similarly, for the **2009** cohort, $F = 0.719$; $df = 2{,}293$; $p = 0.488$ which also shows that the mean scores of the three groups do not differ significantly.

For the two cohorts taken together, $F = 4.487$; $df = 2{,}577$; $p = 0.012$, the mean scores of at least two of the three groups differ significantly. Post hoc Scheffé tests show the difference between the '*pass*' and '*high risk*' group to be statistically significant ($p = 0.039$). This latter result indicates that the Mathematics Access Test could provide additional information as indicator of university achievement and may be useful as inventory in a placement battery.

### 6.5.2 The relation of the SU Physical Science Access Test scores with academic achievement

The 2008 and 2009 cohorts also wrote the Physical Science Access Test (cf. section 5.6.3). Table 6.14 compares mean Physical Science Access Test scores across the three categories of achievement in each of the two different cohorts.

**Table 6.14** ***Mean Physical Science Access Test* Scores *across Cohorts and Academic Achievement Categories***

| Cohort | Status | | | | | |
|---|---|---|---|---|---|---|
| | Pass | | Risk | | High risk | |
| | Mean | SD | Mean | SD | Mean | SD |
| Total | 37.57 | 15.61 | 30.65 | 12.73 | 30.25 | 12.69 |
| 2008 (n = 272) | 42.77 | 14.57 | 39.39 | 13.73 | 38.29 | 12.45 |
| 2009 (n = 286) | 27.79 | 12.54 | 25.64 | 8.91 | 27.65 | 11.68 |

For the **2008** cohort, $F = 2.119$; $df = 2,271$; $p = 0.122$, the mean scores of the three groups of students do not differ significantly. Similarly, for the **2009** cohort, $F = 0.988$; $df = 2,285$; $p = 0.373$, which also shows that the mean scores of the three groups do not differ significantly.

For the two cohorts taken together, $F = 4.258$; $df = 2, 311$; $p = 0.032$, the mean scores of at least two of the three groups differ significantly. Post hoc Scheffé tests show the difference between the '*pass*' and "*high-risk*" group to be statistically significant ($p = 0.039$). This latter result indicates that the Physical Science Access Test could provide additional information as indicator of university achievement and may be useful as inventory in a placement battery.

### 6.5.3 The relation of the Grade 12-profile (M-score/APS) and SU Access Test scores with academic achievement

To examine the contribution of the Mathematics and Physical Science Access Tests toward the prediction of achievement in Mathematics, Chemistry and Physics modules, a series of hierarchical multiple regression analyses are performed. Each hierarchical analysis proceeded in two steps, where the M-score of 2008 (or APS for the 2009 cohort) was entered in the first step, and the Mathematics and Physical Science Access Tests scores were entered in the second step. This procedure allowed for an examination of the predictive power of the Mathematics and Physical Science Access Tests above and beyond the predictive power of the M-score/APS. The relative contribution of the Mathematics and Physical Science Access Tests toward the prediction of academic achievement was evaluated through examination of the change in the proportion of variance in academic achievement explained by the two Access Tests after the contribution of the M-score and APS respectively had been taken into account.

*6.5.3.1 Mathematics in the first-year*

*a. Mathematics 1A (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.15 and Table 6.16. Table 6.15 contains the Pearson correlations between the variables of interest, whereas Table 6.16 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Mathematics 1A.

**Table 6.15** ***Correlations of Mathematics 1A with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 131)***

| Variable | Mathematics1A | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Mathematics 1A | 1.000 | .353* | .363* | .271* |
| M-Score | .353* | 1.000 | .351* | .396* |
| Math Access Test | .363* | .351* | 1.000 | .591* |
| Phys Science Access Test | .271* | .396* | .591* | 1.000 |

* $p < 0.05$

Inspection of Table 6.15 shows that Mathematics 1A correlated most strongly with the Mathematics Access Test ($r = 0.363$), followed by M-score ($r = 0.353$) and then Physical Science Access Test ($r = 0.271$).

**Table 6.16** ***Proportion of Variance in Mathematics 1A explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 131)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $df2$ | $\Delta p$ |
| 1 | .353[a] | .124 | .118 | 12.802 | .124 | 18.344 | 1 | 129 | .000 |
| 2 | .436[b] | .190 | .171 | 12.411 | .065 | 5.120 | 2 | 127 | .007 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.16 shows that M-score on its own accounted for 12.4% of the variance in Mathematics 1A ($\Delta R^2 = 0.124$; $F = 18.34$; $df = 1, 129$; $p < 0.001$), and that the two Access Tests jointly accounted for a further 6.5% of the variance ($\Delta R^2 = 0.065$; $F = 5.12$; $df = 2, 127$; $p = 0.007$). Thus both the M-score and the two Access Tests contributed significantly towards the explanation of student achievement in Mathematics 1A and jointly accounted for 6.5% of the total variance in Mathematics 1A.

*b. Mathematics 1A (2009 cohort)*

The results of the hierarchical regressions are summarised in Table 6.17 and Table 6.18. Table 6.17 contains the Pearson correlations between the variables of interest, whereas Table 6.18

reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Mathematics 1A.

**Table 6.17** ***Correlations of Mathematics 1A with Mathematics and Physical Science Access Test Score and APS for the 2009 Cohort (n = 42)***

| Variable | Mathematics 1A | APS | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Mathematics 1A | 1.000 | .243 | .480* | .360* |
| APS | .243 | 1.000 | .474* | .215 |
| Math Access Test | .480* | .474* | 1.000 | .725* |
| Phys Science Access Test | .360* | .215* | .725* | 1.000 |

* $p < 0.05$

Inspection of Table 6.17 shows that Mathematics 1A correlated most strongly with the Mathematics Access Test ($r = 0.480$), followed by Physical Science Access Test ($r = 0.360$). The correlation of Mathematics 1A with APS was statistically non-significant. .

**Table 6.18** ***Proportion of Variance in Mathematics 1A explained by Mathematics and Physical Science Access Tests Score and APS (cohort 2009) (n = 42)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $df2$ | $\Delta p$ |
| 1 | .243[a] | .059 | .035 | 14.561 | .059 | 2.508 | 1 | 40 | .121 |
| 2 | .481[b] | .231 | .170 | 13.505 | .172 | 4.248 | 2 | 31 | .022 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.18 shows that APS on its own, accounted for 5.9% of the variance in Mathematics 1A ($\Delta R^2 = 0.059$; $F = 2.508$; $df = 1, 40$; $p = 0.121$), and that the two Access Tests jointly accounted for a further 17.2% of the variance ($\Delta R^2 = 0.172$; $F = 4.248$; $df = 2, 31$; $p = 0.022$). Note that the APS did not contribute significantly toward the prediction of Mathematics 1A for the 2009 group. However, the two Access Tests did contribute statistically significantly toward the explanation of student achievement in Mathematics 1A.

*c. Mathematics 1C (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.19 and Table 6.20. Table 6.19 contains the Pearson correlations between the variables of interest, whereas Table 6.20 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Mathematics 1C.

**Table 6.19** ***Correlations of Mathematics 1C with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 39)***

| Variable | Mathematics 1C | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Mathematics 1C | 1.000 | .471* | .410* | .554* |
| M-Score | .471* | 1.000 | .474* | .479* |
| Math Access Test | .410* | .474* | 1.000 | .627* |
| Phys Science Access Test | .554* | .479* | .627* | 1.000 |

* $p < 0.05$

Inspection of Table 6.19 shows that Mathematics 1C correlated most strongly with the Physical Science Access Test ($r = 0.554$), followed by M-score ($r = 0.471$) and then Mathematics Access Test ($r = 0.410$).

**Table 6.20** ***Proportion of Variance in Mathematics 1C explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 39)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $df2$ | $\Delta p$ |
| 1 | .471[a] | .221 | .197 | 13.461 | .221 | 9.104 | 1 | 32 | .005 |
| 2 | .602[b] | .362 | .298 | 12.584 | .141 | 3.310 | 2 | 30 | .050 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.20 shows that M-score on its own accounted for 22.1% of the variance in Mathematics 1C ($\Delta R^2 = 0.221$, $F = 9.104$; $df = 1, 32$; $p = 0.005$), and that the two Access Tests jointly accounted for a further 14.1% ($\Delta R^2 = 0.141$; $F = 3.310$; $df = 2, 30$; $p = 0.050$). The M-score contributed significantly toward the prediction of achievement in Mathematics 1C. Although the contribution of the two Access Tests were non-significant, the $p$-value fell exactly on the border of the criterion for significance ($\alpha = 0.05$). Moreover, the two tests accounted for an additional 14.1% of the variance in achievement in Mathematics 1C. Against this background, it is concluded that the two Access tests contributed meaningfully toward the explanation of student achievement in Mathematics 1C.

*d. Mathematics 1C (2009 cohort)*

The results of the hierarchical regressions are summarised in Table 6.21 and Table 6.22. Table 6.21 contains the Pearson correlations between the variables of interest, whereas Table 6.22 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Mathematics 1C.

**Table 6.21** ***Correlations of Mathematics 1C with Mathematics and Physical Science Access Test Score and APS for the 2009 Cohort (n = 44)***

| Variable | Mathematics 1C | APS | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Mathematics 1C | 1.000 | .226 | .380 | .053 |
| APS | .226 | 1.000 | .643 | .049 |
| Math Access Test | .380 | .643 | 1.000 | .377 |
| Phys Science Access Test | .053 | .049 | .377 | 1.000 |

* $p < 0.05$

Inspection of Table 6.21 shows that Mathematics 1C correlated non-significantly with the Mathematics Access Test, APS, and then Physical Science Access Test. Although non-significant, all of these correlations were positive and therefore in the expected direction.

**Table 6.22** ***Proportion of Variance in Mathematics 1C explained by Mathematics and Physical Science Access Tests Score and APS (cohort 2009) (n = 44)***

| Model | *R* | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | *df*1 | *df*2 | $\Delta p$ |
| 1 | .226[a] | .051 | -.044 | 7.527 | .051 | 0.536 | 1 | 10 | .481 |
| 2 | .396[b] | .157 | -.159 | 7.931 | .106 | 0.504 | 2 | 8 | .622 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.22 shows that APS on its own accounted for 5.1% of the variance in Mathematics 1C ($\Delta R^2$ = 0.051, $F$ = 0.536; $df$ = 1, 10; $p$ = 0.481), and that the two Access Tests accounted for a further 10.6% ($\Delta R^2$ = 0.157; $F$ = 0.504; $df$ = 2, 80; $p$ = 0.622). Note that the APS and the two Access Tests did not contribute statistically significantly toward the prediction of Mathematics 1C for the 2009 group.

*e. Synthesis of results in Mathematics in first-year.*

The above four analyses indicate that in three of the four cases Mathematics at first-year level correlates best with the Mathematics Access Test results. Overall, results show that the M-score remains a significant predictor of Mathematics achievement, but that the APS did not show any statistical significance in any of the two modules. Furthermore, the two Access tests contribute significantly above and beyond the M-score or APS toward the prediction of achievement in Mathematics. For both of the Mathematics modules (1A and 1C) the M-score (in 2008) were more powerful predictors than the Access Test scores. By contrast, in 2009 the Access Tests were more powerful predictors than the APS. Table 6.23 summarises the relative contributions of the M-score/APS and the Access Tests toward the explanation of variance in Mathematics. This table also demonstrates that the indicators of high school achievement and the scholastic aptitude tests jointly account for non-negligible proportions of variance in Mathematics, ranging from about 19% to 36%.

**Table 6.23** ***Proportion of Variance in First-year Mathematics modules explained by Mathematics and Physical Science Access Tests and M-score / APS***

| Module | Cohort | N | Variance explained by the M-score/APS % | Additional variance explained by the Access Tests % | Total variance explained % |
|---|---|---|---|---|---|
| Mathematics 1A | 2008 | 131 | 12.4 | 6.5 | 18.9 |
| | 2009 | 42 | 5.9 | 17.2 | 23.1 |
| Mathematics 1C | 2008 | 39 | 22.1 | 14.1 | 36.2 |
| | 2009 | 44 | 5.1 | 10.6 | 21.0 |

*6.5.3.2 Chemistry in the first-year*

*a. Chemistry 1A (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.24 and Table 6.25. Table 6.24 contains the Pearson correlations between the variables of interest, whereas Table 6.25 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Chemistry 1A.

**Table 6.24** ***Correlations of Chemistry 1A with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 99)***

| Variable | Chemistry1A | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Chemistry1A | 1.000 | .533* | .314* | .352* |
| M-Score | .533* | 1.000 | .280* | .468* |
| Math Access Test | .314* | .280* | 1.000 | .540* |
| Phys Science Access Test | .352* | .468* | .540* | 1.000 |

* $p < 0.05$

Inspection of Table 6.24 shows that Chemistry 1A correlated most strongly with M-score ($r = 0.533$) followed by Physical Science Access Test ($r = 0.352$) and then Mathematics Access Test ($r = 0.314$).

**Table 6.25** ***Proportion of Variance in Chemistry 1A explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 99)***

| Model | *R* | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | *df*1 | *Df*2 | $\Delta p$ |
| 1 | .533[a] | .284 | .275 | 9.264533 | .284 | 32.466 | 1 | 82 | .000 |
| 2 | .561[b] | .315 | .289 | 9.174464 | .031 | 1.809 | 2 | 80 | .170 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.25 shows that M-score on its own accounted for 28.4% of the variance in Chemistry 1A ($\Delta R^2 = 0.284$, $F = 32.466$; $df = 1, 82$; $p = < 0.001$). The two Access Tests jointly accounted for a further 3.1% of the variance ($\Delta R^2 = 0.31$; $F = 1.8093$; $df = 2, 80$; $p = 0.170$), but this contribution was statistically non-significant. The M-score contributed significantly toward the explanation of student achievement in Chemistry 1A in 2008.

*b. Chemistry 1A (2009 cohort)*

The results of the hierarchical regressions are summarised in Table 6.26 and Table 6.27. Table 6.26 contains the Pearson correlations between the variables of interest, whereas Table 6.27 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Chemistry 1A.

**Table 6.26** ***Correlations of Chemistry 1A with Mathematics and Physical Science Access Test Score and APS for the 2009 Cohort (n = 46)***

| Variable | Chemistry1A | APS | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Chemistry 1A | 1.000 | .129 | -.199 | .168 |
| APS | .129 | 1.000 | .375 | -.205 |
| Math Access Test | -.199 | .008 | 1.000 | .683 |
| Phys Science Access Test | .168 | -.126 | .683 | 1.000 |

* $p < 0.05$

Inspection of Table 6.26 shows that Chemistry 1A did not correlate significantly with the APS, Mathematics Access Test, or Physical Science Access Test.

**Table 6.27** ***Proportion of Variance in Chemistry 1A explained by Mathematics and Physical Science Access Tests Score and APS (cohort 2009) (n = 46)***

| Model | *R* | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | *df*1 | *Df*2 | $\Delta p$ |
| 1 | .129[a] | .017 | -.032 | 9.947526 | .017 | 0.341 | 1 | 20 | .566 |
| 2 | .505[b] | .256 | .131 | 9.124071 | .239 | 2.886 | 2 | 18 | .082 |

a. Predictors: (Constant), M-Score/APS

b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.27 shows that APS on its own accounted for 1.7% of the variance in Chemistry 1A ($\Delta R^2 = 0.071$, $F = 0.341$; $df = 1, 20$; $p = 0.566$), and that the two Access Tests accounted for a further 23.9%. Neither of the two sets of variables contributed significantly toward the prediction of performance in Chemistry 1A.

*c. Chemistry 1C (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.28 and Table 6.29. Table 6.28 contains the Pearson correlations between the variables of interest, whereas Table 6.29 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Chemistry 1C.

**Table 6.28** ***Correlations of Chemistry 1C with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 88)***

| Variable | Mathematics 1A | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Chemistry 1C | 1.000 | .503* | .349* | .396* |
| M-Score | .503* | 1.000 | .339* | .413* |
| Math Access Test | .349* | .339* | 1.000 | .624* |
| Phys Science Access Test | .396* | .413* | .624* | 1.000 |

* $p < 0.05$

Inspection of Table 6.28 shows that Chemistry 1C correlated most strongly with M-score ($r = 0.503$) followed by Physical Science Access Test ($r = 0.396$) and then Mathematics Access Test ($r = 0.349$).

**Table 6.29** ***Proportion of Variance in Chemistry 1C explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 88)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $Df2$ | $\Delta p$ |
| 1 | .503[a] | .253 | .244 | 11.624 | .253 | 29.140 | 1 | 86 | .000 |
| 2 | .555[b] | .308 | .283 | 11.319 | .055 | 3.344 | 2 | 84 | .040 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.29 shows that M-score on its own accounted for 25.3% of the variance in Chemistry 1C ($\Delta R^2 = 0.253$, $F = F = 29.140$; $df = 1, 86$; $p < 0.001$), and that the two Access Tests jointly accounted for a further 5.5% of the variance ($\Delta R^2 = 0.055$, $F = 3.344$, $df = 2, 84$, $p = 0.040$). The M-score and the Access Tests contributed significantly toward the explanation of student achievement in Chemistry 1C in 2008.

*d. Chemistry 1C (2009 cohort)*

The results of the hierarchical regressions are summarised in Table 6.30 and Table 6.31. Table 6.30 contains the Pearson correlations between the variables of interest, whereas Table 6.31 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Chemistry1C.

**Table 6.30** ***Correlations of Chemistry 1C with Mathematics and Physical Science Access Test Score and APS for the 2009 Cohort (n = 58)***

| Variable | Chemistry1C | APS | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Chemistry1C | 1.000 | .022 | -.073 | -.076 |
| APS | .022 | 1.000 | .375 | .205 |
| Math Access Test | -.073 | .375 | 1.000 | .524 |
| Phys Science Access Test | -.076 | .205 | .524 | 1.000 |

* $p < 0.05$

Inspection of Table 6.30 shows that Chemistry1C did not correlate significantly with Physical Science Access Test, Mathematics Access Test or APS.

**Table 6.31** ***Proportion of Variance in Chemistry 1C explained by Mathematics and Physical Science Access Tests Score and APS (cohort 2009) (n = 58)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $Df2$ | $\Delta p$ |
| 1 | .022[a] | .000 | -.017 | 17.130 | .000 | 0.027 | 1 | 56 | .869 |
| 2 | .102[b] | .010 | -.045 | 17.357 | .010 | 0.271 | 2 | 54 | .763 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.31 shows that APS on its own accounted for 0.0% of the variance in Chemistry 1C ($\Delta R^2$ = 0.0; $F$ = 0.027; $df$ = 1, 56; $p$ = 0.869), and that the two Access Tests jointly accounted for a further 1.0% of the variance ($\Delta R^2$ = 0.1; $F$ = 0.271; $df$ = 2, 54; $p$ = 0.763). Neither of the two sets of variables contributed statistically significantly toward the explanation of student achievement in Chemistry 1C for 2009.

*e. Synthesis of results in Chemistry in first-year.*

Overall, results show that the M-score is a significant predictor of Chemistry achievement in 2008, and that the two Access tests were more powerful predictors than the APS toward the prediction of achievement in Chemistry 1A in 2009. Table 6.23 summarises the relative contributions of the M-score/APS and the Access Tests toward the explanation of variance in Chemistry. On average, the aggregate high school mark (M-score or APS) and the access tests jointly accounted for a non-negligible amount of variance in Chemistry performance (between about 25 to 30%). The 2009 cohort appears to be an outlier in this respect

**Table 6.32** ***Proportion of Variance in First-year Chemistry modules explained by Mathematics and Physical Science Access Tests and M-score / APS***

| Module | Cohort | n | Variance explained by the M-score/APS % | Additional variance explained by the Access Tests % | Total variance explained % |
|---|---|---|---|---|---|
| Chemistry 1A | 2008 | 99 | 28.4 | 3.1 | 31.5 |
| | 2009 | 46 | 1.7 | 23.9 | 25.6 |
| Chemistry 1C | 2008 | 88 | 25.3 | 5.5 | 30.8 |
| | 2009 | 58 | 0 | 1 | 1.0 |

In both cases of the 2008-cohort did the M-score contribute primarily toward the first-year achievement. However, in the case of the 2009-cohort, the Access Test results contributes more to the predictability toward first-year Chemistry 1A achievement. None of the variables made a significantly contribution towards the explanation of student achievement in Chemistry 1C in 2009.

*6.5.3.3 Physics in the first-year*

*a. Physics 1A (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.33 and Table 6.34. Table 6.33 contains the Pearson correlations between the variables of interest, whereas Table 6.34 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Physics 1A.

**Table 6.33** ***Correlations of Physics 1A with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 103)***

| Variable | Physics1A | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Physics 1A | 1.000 | .106 | .070 | .112 |
| M-Score | .106 | 1.000 | .339 | .413 |
| Math Access Test | .070 | .339 | 1.000 | .624 |
| Phys Science Access Test | .112 | .413 | .624 | 1.000 |

* $p < 0.05$

Inspection of Table 6.33 shows that Physics 1A did not correlate significantly with Physical Science Access Test, M-score, or Mathematics Access Test.

**Table 6.34** ***Proportion of Variance in Physics 1A explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 103)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $Df2$ | $\Delta p$ |
| 1 | .106[a] | .000 | -.013 | 11.901 | .000 | 0.026 | 1 | 75 | .874 |
| 2 | .218[b] | .048 | .008 | 11.775 | .047 | 1.810 | 2 | 73 | .171 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.34 shows that M-score on its own accounted for 0% of the variance in Physics 1A ($R^2$ = 0.0; $F$ = 0.026; $df$ = 1, 75; $p$ = 0.874), and that the two Access Tests jointly accounted for a further 4.7% of the variance ($\Delta R^2$ = 0.047; $F$ = 1.810; $df$ = 2, 73; $p$ = 0.171). Neither the M-score nor the Access Tests contributed statistically significantly towards the explanation of student achievement in Physics 1A.

*b. Physics 1A (2009 cohort)*

The results of the hierarchical regressions are summarised in Table 6.35 and Table 6.36. Table 6.35 contains the Pearson correlations between the variables of interest, whereas Table 6.36 reflects the relative contributions of the different sets of predictor variables toward the prediction of success in Physics 1A.

**Table 6.35** ***Correlations of Physics 1A with Mathematics and Physical Science Access Test Score and APS for the 2009 Cohort (n = 42)***

| Variable | Physics1A | APS | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Physics 1A | 1.000 | .176 | .561* | .241 |
| APS | .176 | 1.000 | .375* | .205 |
| Math Access Test | .561* | .375* | 1.000 | .524* |
| Phys Science Access Test | .241 | .205 | .524* | 1.000 |

* $p < 0.05$

Inspection of Table 6.35 shows that Physics1A correlated most strongly with Mathematics Access Test ($r$ = 0.561), followed by Physical Science Access Test ($r$ = 0.241). The correlation with APS was non-significant.

**Table 6.36** ***Proportion of Variance in Physics 1A explained by Mathematics and Physical Science Access Tests Score and APS (cohort 2009) (n = 42)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df1$ | $Df2$ | $\Delta p$ |
| 1 | .176[a] | .031 | -.015 | 11.960 | .031 | 0.669 | 1 | 21 | .422 |
| 2 | .598[b] | .357 | .256 | 10.241 | .326 | 4.820 | 2 | 19 | .020 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.36 shows that APS on its own accounted for 3.1% of the variance in Physics 1A ($R^2$ = 0.031; $F$ = 0.669; $df$ = 1, 21; $p$ = 0.422), and that the two Access tests jointly accounted for a further 32.6% of the variance ($\Delta R^2$ = 3.26; $F$ = 4.820; $df$ = 2, 19; $p$ = 0.020). Note that the APS did not contribute toward the prediction of Physics 1A for the 2009 group. However, the two Access tests did contribute statistically significantly toward the explanation of student achievement in the Physics 1A.

*c. Physics 1C (2008 cohort)*

The results of the hierarchical regressions are summarised in Table 6.37 and Table 6.38. Table 6.37 contains the Pearson correlations between the variables of interest, whereas Table 6.38 reflects the relative contributions of the different sets of predictor variables toward the explanation of student achievement in Physics 1C.

**Table 6.37** ***Correlations of Physics 1C with Mathematics and Physical Science Access Test Score and M-score for the 2008 Cohort (n = 81)***

| Variable | Physics 1C | M-Score | Maths Access Test | Phys Science Access Test |
|---|---|---|---|---|
| Physics 1C | 1.000 | .652* | .451* | .491* |
| M-Score | .652* | 1.000 | .474* | .297* |
| Math Access Test | .451* | .474* | 1.000 | .455* |
| Phys Science Access Test | .491* | .297* | .455* | 1.000 |

* $p < 0.05$

Inspection of Table 6.37 shows that Physics 1C correlated most strongly with M-score ($r$ = 0.652) followed by Physical Science Access Test ($r$ = 0.491) and then Mathematics Access Test ($r$ = 0.451).

**Table 6.38** ***Proportion of Variance in Physics 1C explained by Mathematics and Physical Science Access Tests Score and M-score (cohort 2008) (n = 81)***

| Model | $R$ | $R^2$ | Adjusted $R^2$ | SE | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\Delta R^2$ | $\Delta F$ | $df$1 | $Df$2 | $\Delta p$ |
| 1 | .652[a] | .425 | .416 | 10.981 | .425 | 50.223 | 1 | 68 | .000 |
| 2 | .724[b] | .525 | .503 | 10.134 | .100 | 6.922 | 2 | 66 | .002 |

a. Predictors: (Constant), M-Score/APS
b. Predictors: (Constant), M-Score/APS, Math Access Test, Science Access Test

Table 6.38 shows that M-score on its own accounted for 42.5% of the variance in Physics 1C ($\Delta R^2$ = 42.5; $F$ = 50.223; $df$ = 1, 68; $p$ < 0.001), and that the two Access Tests accounted for a further 10.0% ($\Delta R^2$ = 0.01; $F$ = 6.922; $df$ = 2, 66; $p$ = 0.002). Both the M-score and the two Access Tests contributed significantly toward the explanation of student achievement in Physics 1C.

*d. Synthesis of results in Physics in first-year.*

The sample for Physics 1C in 2009 constituted only 12 participants, which was too small to allow meaningful analysis. The three analyses reported in the preceding paragraphs indicate that in all three cases Physics at first-year level correlates best with the Physical Science Access Test results. The amount of variance jointly explained by the M-Score/APS and the Access Tests varied across the three analyses, ranging from about 5% (Physics1A in 2008) to 52.5% (Physics 1C in 2008).

**Table 6.39** ***Proportion of Variance in First-year Physics modules explained by Mathematics and Physical Science Access Tests and M-score / APS***

| Module | Cohort | N | Variance explained by the M-score/APS % | Additional variance explained by the Access Tests % | Total variance explained % |
|---|---|---|---|---|---|
| Physics 1A | 2008 | 103 | 0 | 4.7 | 4.7 |
| | 2009 | 42 | 3.1 | 32.6 | 35.7 |
| Physics 1C | 2008 | 81 | 42.5 | 10 | 52.5 |

* Note that Physics 1C (2009) sample to small to allow meaningful analysis

## 6.6 THE RELATION BETWEEN ACADEMIC ACHIEVEMENT OF FIRST-YEAR UNIVERSITY STUDENTS AND MEASURED NON-COGNITIVE ATTRIBUTES

To determine the relation between the measurements of non-cognitive (personality attributes and study orientation) and academic achievement of first-year modules there has to be comparisons focused on the success at university. This section examines the influence of other indicators than school and proficiency results covered above.

To determine if there was statistically significant relation between the scales of the Basic Traits Inventory and Study Orientation in Mathematics Tertiary with academic achievement, multivariate analyses of variance were conducted. Table 6.40 presents the mean BTI score across the three categories of achievement in each of the three different cohorts.

Inspection of the means in Table 6.40 shows that in comparison with the '*risk*' and '*high risk*' groups the '*pass*' group scored higher on conscientiousness, lower on neuroticism, openness, extroversion and agreeableness. The observed pattern for neuroticism and conscientiousness corresponds with existing body of knowledge regarding personality and academic achievement (De Raad 1992:19-20, McCrae and Costa 1991:370 and Taylor & De Bruin 2004:11-36).

**Table 6.40** ***Relationship between BTI factors and Academic Achievement in the Total group and Cohorts (2006 to 2008)***

| Cohort | BTI FACTOR | | Status | | |
|---|---|---|---|---|---|
| | | | Pass | Risk | High risk |
| 2006 | BTI 1 | *N* | 153 | 34 | 53 |
| | (Extroversion) | *Mean* | 117.36 | 121.32 | 120.62 |
| | | *SD* | 19.73 | 13.36 | 15.57 |
| | BTI 2 | *N* | 153 | 34 | 53 |
| | (Neuroticism) | *Mean* | 88.41 | 89.26 | 88.36 |
| | | *SD* | 21.37 | 23.83 | 32.87 |
| | BTI 3 | *N* | 153 | 34 | 53 |
| | (Conscientiousness) | *Mean* | 157.70 | 156.97 | 153.16 |
| | | *SD* | 24.27 | 22.74 | 20.60 |
| | BTI 4 | *N* | 152 | 34 | 53 |
| | (Openness) | *Mean* | 118.78 | 119.62 | 121.47 |
| | | *SD* | 16.39 | 17.45 | 13.47 |
| | BTI 5 | *N* | 153 | 34 | 53 |
| | (Agreeableness) | *Mean* | 131.40 | 131.38 | 133.02 |
| | | *SD* | 17.99 | 13.83 | 13.43 |
| 2007 | BTI 1 | *N* | 106 | 18 | 39 |
| | (Extroversion) | *Mean* | 116.17 | 116.94 | 123.48 |
| | | *SD* | 29.21 | 16.81 | 12.98 |
| | BTI 2 | *N* | 106 | 18 | 39 |
| | (Neuroticism) | *Mean* | 79.99 | 90.39 | 85.31 |
| | | *SD* | 25.43 | 18.03 | 16.70 |
| | BTI 3 | *N* | 106 | 18 | 39 |
| | (Conscientiousness) | *Mean* | 156.67 | 149.53 | 145.00 |
| | | *SD* | 36.73 | 19.13 | 20.62 |
| | BTI 4 | *N* | 106 | 18 | 39 |
| | (Openness) | *Mean* | 114.86 | 115.33 | 120.13 |
| | | *SD* | 28.72 | 15.99 | 11.43 |
| | BTI 5 | *N* | 106 | 18 | 39 |
| | (Agreeableness) | *Mean* | 125.23 | 130.39 | 131.59 |
| | | *SD* | 30.46 | 11.64 | 11.44 |
| 2008 | BTI 1 | *N* | 123 | 28 | 27 |
| | (Extroversion) | *Mean* | 120.81 | 119.29 | 120.48 |
| | | *SD* | 17.84 | 16.77 | 12.53 |
| | BTI 2 | *N* | 131 | 29 | 26 |
| | (Neuroticism) | *Mean* | 96.24 | 102.20 | 97.23 |
| | | *SD* | 20.56 | 26.65 | 18.30 |
| | BTI 3 | *N* | 131 | 28 | 26 |
| | (Conscientiousness) | *Mean* | 166.43 | 154.03 | 156.85 |
| | | *SD* | 26.18 | 24.69 | 17.92 |
| | BTI 4 | *N* | 127 | 28 | 26 |
| | (Openness) | *Mean* | 114.25 | 121.18 | 119.23 |
| | | *SD* | 20.44 | 15.51 | 15.68 |
| | BTI 5 | *N* | 124 | 28 | 26 |
| | (Agreeableness) | *Mean* | 127.09 | 135.18 | 123.96 |
| | | *SD* | 20.12 | 18.67 | 25.30 |

Table 6.41 contains the results of the multivariate test of mean differences on the BTI scales.

**Table 6.41** ***Multivariate Test of Mean Differences on the BTI scales for Cohorts (2006 to 2008)***

| Cohort | Wilks lambda | *F* | *df* 1 | *df* 2 | *p* | $\eta^2$ |
|---|---|---|---|---|---|---|
| 2006 | .980 | .478 | 10 | 464 | .904 | .010 |
| 2007 | .934 | 1.091 | 10 | 312 | .369 | .034 |
| 2008 | .918 | 1.495 | 10 | 342 | .139 | .041 |

These results show that the personality attributes made a statistically non-significant contribution towards the explanation of student achievement. Group status (the three academic achievement categories) shared a relatively small proportion of variance with the multivariate combination of the five traits across all three cohorts (approximately 1% in 2006, 3.4% in 2007, and 4.1% in 2008).

Scores on the Study Orientation in Mathematics Tertiary were compared across the three categories of achievement in each of the cohorts and displayed in Table 6.42.

**Table 6.42** ***Relationship between SOMT (total) and Academic Achievement in the Total Group and Cohorts (2006 to 2008)***

| Cohort | | Status | | | Total |
|---|---|---|---|---|---|
| | | Pass | Risk | High risk | |
| 2006 | *N* | 144 | 20 | 33 | 197 |
| | *Mean* | 72.42 | 67.08 | 60.65 | 67.32 |
| | *SD* | 22.89 | 19.99 | 20.74 | 22.36 |
| 2007 | *N* | 155 | 18 | 50 | 223 |
| | *Mean* | 71.94 | 70.12 | 66.66 | 70.25 |
| | *SD* | 23.27 | 21.53 | 25.37 | 23.55 |
| 2008 | *N* | 68 | 13 | 12 | 93 |
| | *Mean* | 70.95 | 68.15 | 66.50 | 69.99 |
| | *SD* | 23.05 | 21.48 | 22.38 | 23.56 |

Table 6.42 shows that the '*pass*' group obtained higher mean scores than the other two categories of achievement across all three of the three cohorts. These results show that the total SOMT could contribute towards the explanation of student achievement and accords with theoretical expectation (Eiselen 2006:74 and Maree 2005:86-92).

Table 6.43 contains the results of the univariate test of mean differences on the SOMT scales.

**Table 6.43** ***Univariate Test of Mean Differences on the SOMT scales for Cohorts (2006 to 2009)***

| Cohort | *F* | *df* 1 | *df* 2 | *p* | $\eta^2$ |
|---|---|---|---|---|---|
| 2006 | 1.771 | 2 | 194 | .713 | 0.018 |
| 2007 | 0.338 | 2 | 220 | .713 | 0.003 |
| 2008 | 0.224 | 2 | 90 | .800 | 0.005 |

These results show that the personality attributes for the most part made a statistically non-significant contribution towards the explanation of student achievement. Group status (the three academic achievement categories) shared a relatively small proportion of variance with the univariate combination of SOMT across all three cohorts (approximately 1.8% in 2006, 0.3% in 2007, and 0.5% in 2008).

The two instruments measuring non-cognitive attributes indicate that conscientiousness (BTI) and study orientation in Mathematics (SOMT) are positive indicators of student's success in Science.

## 6.7 SYNTHESIS

The relations of various variables with academic achievement in the first-year were examined. The following variables to be significantly related with student achievement were found:

- Optometry students performed better than the Engineering students, who in turn were more successful then the Science students (cf. Section 6.2). The Optometry programme has a selection process where the 40 best candidates are selected from about 200 applicants per year.
- Older students tend to perform better than younger students (cf. Section 6.3). This result could be attributed to the higher level of maturity of older students.
- Home-language and ethnicit*y* contribute significantly towards the explanation of performance in first-year studies. (cf. Section 6.3). Black students with indigenous African home languages performed weaker than the other ethnic groups and students from other home language groups. This study did not pursue an investigation to find reasons towards this complex problem and a multitude of questions arise.
- At most universities in South Africa, admission will be based on overall Grade 12-results. This study indicates that the M-score (2007 and 2008) and APS (2009) contribute statistically significantly towards the prediction of performance in first-year studies. These indicators combine performance across all the school subjects and reflect prior learning and academic proficiency and in part also reflect study habit (cf. Section 4.6), attitude (cf. Sections 4.4 and 4.7) and interest (cf. Section 4.5).
- Grade 12 English, Grade 12 Mathematics and Grade 12 Physical Science contribute towards the explanation of performance in first-year studies (cf. Section 6.4).
- The SU Access Test results (cf. Section 6.5) allow for a meaningful and statistically significant distinction between successful and unsuccessful university students. The SU

Mathematics Access Test and the Physical Science Test can be used as predictors of success. However, they may be most useful if they are combined with school results.

The relations of various variables with academic achievement in the first-year were examined and the following variables presented as moderate indicators of success in Sciences modules in the first-year:

In the non-cognitive profiling of successful students, the Basics Trait Inventory (BTI) and the Study Orientation in Mathematics Tertiary (SOMT) showed statistical significance with student academic achievement in the above analysis (cf. Section 6.6). These results are expected as all the available literature indicates that personality; interest, anxiety and other non-cognitive attributes have influence on academic achievement and could be used as indicators.

Finally, the above results indicate that there is very little relation between gender and academic success in the first-year (cf. Section 6.3.2). The Physical Science results in Grade 12 had a poor predictability for Physics at first-year level (cf. Section 6.5.3), but had better indication of Chemistry achievement (cf. Section 6.5.3).

The following chapter provides deductions from the results found in this chapter. The proposed framework based on foundational principles and guidelines for implementation. The alignment of the methodology and results is discussed. The final chapter will provide limitations of the investigation considered, recommendations for any future research are made and the conclusions from this study are drawn.

# CHAPTER 7

## *TOWARDS A FRAMEWORK FOR PLACEMENT*

## 7.1 INTRODUCTION

This chapter presents the deductions made from the literature review and empirical results. The deductions are used towards the development of a framework for placement of first-year students in Science and related programmes. Deductions are clustered in categories that provide the foundational principles towards the framework. This chapter culminates in the presentation of a framework for placement of university students in Science programmes.

## 7.2 DEDUCTIONS IN RESPECT OF THE LITERATURE AND EMPIRICAL RESEARCH

The deductions below are derived from a review of the relevant literature and a synthesis of empirical results. In the context of this study, available information, namely the literature and empirical analysis, are utilised to deduce and observe interdependent trends, and possible indicators in finding a solution to the purpose of the research, namely to develop a framework for the placement of first-year Science students.

The deductions are structured in three categories, namely, (a) deductions generally applicable to the Higher Education context, (b) deductions that relate to the teaching of Science in particular, and (c) deductions focused on student success in the first year. This categorization is illustrated in Figure 1.1 (p 2). In the paragraphs that follow the deductions related to each of these categories are presented in turn.

### 7.2.1 Literature-based deductions related to the Higher Education context

South African policy directives dictate widened access, with an emphasis in providing Higher Education opportunities to more students from disadvantages backgrounds and a poor schooling system. Various policies direct the widening of access to Higher Education to accommodate the diverse population of the country and furthermore respond towards the national need for Science graduates. Efficiency within the Higher Education sector and provision of quality programmes and learning opportunities are directives guiding processes and procedures within universities (cf. Section 2.3). Each of these aspects need to be monitored and implemented by individual universities.

The concept of “widened access” means that more students are given the opportunity to enter into Higher Education and measures are taken to ensure that this broad and diverse base of first-year students are successful students (cf. Sections 2.3.4, 2.6.2 3.5.3 and Table 2.7). The increase of Black student participation from about 12% in 1993 to about 63% in 2006 indicates that the access goals were largely met (NCHE 1996:64 and Bundy 2006:12). At the University of Johannesburg an overall increase of 40% in first-year enrolments in three faculties at UJ (cf. Table 5.1) has taken place from 2004 to 2009. In particular, the proportion of Black students has increased from 41% in 2006 to 66% in 2009 (cf. Section 5.5.4). This finding indicates that the directives with respect to widened access, increased diversity and greater responsiveness to societal needs have been partially addressed. However, Bunting (2004c:90 and 2008:5) and Scott (2007:2 and 2009:22) remark that Black students still represent a highly selected group of the population. Students from very ‘poor’ schools still find it difficult to access universities because they fail to meet admission requirements. This raises questions about what universities could do in addition to what they are already doing, to provide greater access and opportunities for students from disadvantaged backgrounds.

South African universities began paying close attention to management aspects of enrolment almost a decade ago. The literature review shows that several universities have adopted two strategies that have the common goal of graduating more students with required competencies and skills:

- The first strategy is the development of extended and foundation programmes that aim to provide under-prepared students with foundational support (cf. Section 2.3.2). This initiative is supported by earmarked funding from the Department of Education (RSA DoE 2001:10).
- Another strategy is the design of reliable and valid indicators of academic potential (cf. Foxcroft & Stumpf 2005:7-10; Maree *et al.* 2006:229; Huysamen 2002a:139-147, and Rademeyer & Schepers 1998:33-40). These researchers pointed out that school results do indeed provide a good indication of university success, but that other characteristics and skills, such as personality and study skills also need to be taken into account to better understand student performance. Against this background universities have developed tailor-made instruments that can be used to assess academic competency, such as the Stellenbosch University Access Test, Standarised Assessment Tests for Access and Placement, and Placement Test in English for Educational Purposes (cf. Sections 2.6 and 3.5.2).

The real challenge remains to 'discover' or craft additional tailor-made indicators of academic potential (Foxcroft 2009), which would also meet student-specific needs (e.g. language or field and programme-specific characteristics). The following deductions from the literature review are also noteworthy:

- Higher Education South Africa is so concerned with the quality of students entering into universities that they commissioned the development of the National Benchmark Test. The results of this test are to be used as a gauge of the quality of prior learning and of academic literacy levels of entering first-year students (cf. Section 2.6). Yeld (2009b), Foxcroft (2009) and Nel and Kistner (2009:65) have demonstrated the value of this instrument.
- The quality of teaching and learning during the school years impacts on the success of university students. The Grade 10 to 12 curriculum, and its new levels of learner competency, has resulted in a change of focus (in respect of content and outcomes for teachers as well as learners). Indeed, from the perspectives of universities, the poor performance of first-year students exposes the weaknesses in the current schooling system (SAIRR 2009b). These weaknesses can be attributed to many sources, such as the dearth of suitably qualified and experienced teachers (cf. Sections 2.6.2 and 3.4.1), the lack of appropriate infrastructure in many schools, and the upward adjustment of Grade 12-results by education authorities (cf. Section 3.4.1).
- The contribution of individual differences such as personality, interest and motivation had previously been neglected with admission to university. Hay (2008:943) and De Bruin (2000:79) related academic performance to personality, self-directedness and problem-solving skills. These findings strengthened the argument that school results alone can no longer be the only criteria for admission echoed by Bitzer (2005:178). A confirmation by McCrae and Costa (1991:72) states that personality is relevant as predictor of academic achievement while Taylor (2008:21) refined the influence of personality traits for the South-African multi-cultural and multi-lingual population (cf. Section 4.3.4). Maree (2008:38) relate academic performance to self-esteem which, in combination with content, skills and attitudes established at home and at school, is important for success at university (cf. Section 3.5.2).
- To facilitate academic success of first-year students, universities have to align their curricula and teaching strategies with the academic culture cultivated at school level. Biggs and Tang (2007:11), Gravett (2004:27) and Anthony (2000:5) state that good university teaching would inspire most students to achieve and link the new content to

the prior knowledge base. The usual assumptions university lecturers make about the readiness of first-year students are often proven to be wrong (cf. Section 4.6.4). In this respect Grayson (1997:109) emphasize that lecturers are expected to provide under-prepared students with the necessary support in terms of study skills (cf. Section 4.6.2).

- Research performed on the National Benchmark Test (Yeld 2009a), indicates that only 50% of first-year students posses the academic literacy skills to be successful at university. This emphasizes the need for language support, study skills development and training in time management (these aspects are commonly addressed in extended and foundation programmes). Overall, reports on the success of these programmes are positive, and several students from such programmes have been able to progress to post-graduate programmes (UJ 2008b).

### 7.2.2 Literature-based deductions related to the teaching of Science

As discussed above Higher Education policy directives emphasises widened access in general. The following deductions focus on the shortage of students in Science and related disciplines (NCHE 1996:6). Science skills (including Engineering, Agricultural and Health Sciences) are labelled scarce skills. The enrolment of more Science students would benefit institutions financially, as these programmes generate higher income for universities (RSA DoE 2008).

All over the world universities rely on Mathematics and Science content taught at school level as preparation for university level training (cf. Section 3.4.1.1 and Arnold 2005:52; Khan 2004:155; Zwick 2007:5). Learners start with Mathematics and Science in the Intermediate phase (Grades 4 to 6), continue into the Senior phase (Grades 7 to 9), and then specialise in the Further Education and Training phase (Grades 10 to 12). This implies that when they enter university, students should be able to cope with first-year content at university (cf. Section 2.6.1). For studies in the Sciences most universities require a demonstrated level of proficiency in high school Mathematics (and for some programmes Physical Science or Biology). Indeed, Mathematics is a component of almost every academic aptitude test battery (cf. Section 3.4.1.1) and it serves as a salient admission requirement due to its predictive validity (Eiselen *et al.* 2006:39).

This study showed that an increased number of learners pass Mathematics and Physical Science at school (cf. Section 2.6.1.2 and Figure 2.11). However, at universities proportionally more students experience problems with the three “gateway” subjects, namely Mathematics, Physics and Chemistry since the new school curriculum has been implemented. Science-related faculties acknowledge that there are many reasons for the poor performance of students. Deductions from this study that are related to university performance in Science are outlined briefly below:

- Reddy (2003) expresses concern that past inequalities with respect to the provision of qualified teachers, facilities and other resources still exist in schools. Well resourced schools provide learners with quality teaching and these learners are more prepared for university study than their counterparts from poorly resourced schools. It remains true that schools in former White suburbs, are better resourced than the schools in townships and rural areas with predominantly Black learners (cf. Section 3.4.2.3).
- A shortage of Mathematics and Science teachers remains a global theme of conversation (cf. Section 3.4.1). Rademeyer (2009:395) reports that in 2008 only 13% of Mathematics and Mathematics Literacy teachers were appropriately qualified and that only 4% of the 66% qualified Physical Science teachers were actually teaching Science (Naidoo and Lewin 1998:73). Minister Pandor (RSA DoE 2008) expressed concern about a shortfall of 6 000 Mathematics teachers. In total, South Africa needs 21 000 newly qualified teachers per year, yet less than 5 000 new teachers qualify annually (cf. Sections 2.6.1.3 and 3.4.2.3 and Sunday Argus 2009:4).
- From 1994, onwards, the school curriculum has changed fundamentally. The 2009 cohort of first-year students was the first group to enter Higher Education with a National Senior Certificate based on the 'new' curriculum (cf. Table 2.8). As the new National Curriculum Statement (NCS) does not differentiate between Higher and Standard grade (cf. Section 2.6.1), and this curriculum is pitched between these two levels, universities had no benchmark against which to evaluate high school marks (Umalusi 2009). A greater number of learners than before passed Grade 12, with more passing Mathematics (cf. Table 2.6), although there had not been a sufficient number of teachers to teach Mathematics, let alone Mathematical Literacy.
- Since 2004 the Physical Science curriculum has changed comprehensively and now contains content that previously were covered at university level (RSA DoE 2003:1-93). With very difficult content to teach, together with the quality of teaching decreasing, the problem with Science as a scarce skill is elevated (cf. Section 3.4.3.1). Another severe impact on Higher Education (Masehela 2005:21) is the fact that only one out of every five Black learners in South Africa chooses to study Physical Science.
- The pool of Science students at universities is extremely small. According to the DoE (2008:13), only 20% of all Grade 12-learners qualify for undergraduate studies, while

23% qualify for diploma studies (cf. Sections 3.4.2.1 and 3.4.2.3). Sixteen percent of these learners pass Mathematics, and 7% pass Physical Science in Grade 12. Although there is evidence of growth in enrolments in Mathematics and Physical Science in high school (see Table 2.6) several of these learners select non-Science fields of study such as Commerce and Law (SAIRR 2008a:1).

- Students' achievement in Science and Mathematics is influenced by their language abilities and competencies (cf. Section 3.4.1.3). Maree (1994:118-277) revealed that learners perform better in Mathematics when they are instructed in their home language. The present study confirmed that students from an indigenous African language background are less successful than students from English and Afrikaans home language backgrounds (see Table 6.8). This may be due in part to the switching of codes from home language to scientific discourse (Matoti and Lekhu 2008:128). Foxcroft and Stumpf (2005:15) propose that language support and development be compulsory for all South-African students.
- Science and Mathematics require of students to deal with complexities and abstract material (Wittenborn 2004:2 and Gottfredson 1998:24). Students who perform well in Science are able to solve abstract problems, learn quickly and efficiently, and reason well (cf. Section 3.4.2.2). Against this background universities and educational authorities have commissioned the development of tests, such as the Stellenbosch University Access Test (cf. Section 3.5.2.1) and the National Benchmark Test (cf. Sections 3.4.1.1 and 3.5.2.4) that can identify these required abilities and competencies.
- Researchers (Maree 2006:229; Engelbrecht *et al*. 2009:289; Du Preez, Steyn and Owen 2008:50-52) express concern about the level of preparedness of first-year students in calculus, algebraic manipulation and mathematical formulation (cf. Sections 2.6.2 and 3.4.1.1). In 2009 the Engineering group who entered with a Grade 12-average of 70% in Mathematics, shifted to an average of 40% in first-year Mathematics indicating a drop in performance and this is reason for concern (cf. Figure 3.8).
- According to Yeld (2009a), the proficiency of Mathematics students showed that only 7.6% in the pilot study found themselves in the proficiency band (cf. Figure 3.14). The NBT exposes students with results above 80% in Grade 12 Mathematics, but who objectively have poor 'basic' Mathematics competency. The Star (11 August 2009:3) reported these results as "…the reality at South-African universities…"
- The teaching approach at university level is increasingly being put under pressure. With growing numbers of under-prepared students being admitted and university

management demanding better throughput, academics are confronted with various challenges and problems. These challenges and problems are unlikely to be resolved in the near future and therefore lecturer's perceptions about students must be modified (cf. Sections 3.5.3 and 4.6.1). In this respect Hay and Marais (2004:59-75) report that the opinions and expectations many university colleagues have of students should be changed, rather than the course content or teaching strategies. Staff members at universities are likely to have been top achievers themselves and may find it difficult to understand the lack of preparedness of students (Zeegers and Klinger 2003).

- Finally, the last deduction relate to the real contact with the student in the lecture. Schwartz (2006:51) make two relevant statements about Higher Education and teaching, namely that the lecturer contributes to the learning environment with compassion and knowledge, but that he/she should begin their teaching at an appropriate level (cf. Sections 4.3.6 and 4.6.2). Biggs and Tang (2007:7) emphasize the "starting point" as a common problem that occurs in most teaching situations. Some students are more dependent of a compassionate lecturer and a structured support system.

### 7.2.3 Empirical deductions related to Science students

The empirical findings are derived from an analysis of the data of four cohorts of first-year students in Science, Optometry and Engineering programmes at the University of Johannesburg. The deductions are based on the biographical profile, school results and subsequent results of additional instruments and performance after the first semester at university.

The overarching aim of the empirical component was to identify valid and reliable indicators or predictors of student success in Science modules. Five empirical research objectives were formulated in Chapter 5 (cf. Section 5.3.1). The objectives and research deductions pertaining to each are discussed below:

i) To examine the relation between biographical variables (i.e. field of study, gender, age, home language and ethnicity) and first-year performance in Science modules.

- Optometry students achieve better performance than Engineering and Science students (cf. Section 5.6). One reason for this is the competitive admission process in Optometry where a limited number of places are available and students are admitted on the basis of their Grade 12-achievement.

- Although Wigfield and Eccles in Aronson (2002:176) and Eiselen (2006:86) found significant relations between gender and performance in Mathematics, this study show no significant correlation (cf. Table 6.5). Contrary to expectation men and women perform equally well.
- This investigation indicate that older students perform better than their younger counterparts. Eiselen (2006:72) found similar results and reasoned that younger students withdrew if they were unsuccessful (cf. Table 6.6).
- Home language has a significant correlation with performance in Science modules at university level (cf. Table 6.7). More students from indigenous African home language groups are placed in the '*high risk*' category than students with a background of English, Afrikaans or even 'other' languages as home languages. In this regard Bundy (2006:12) remarked that a "wasteful" number of Black students fail to complete their studies. Scott (2007) quantifies this to one out of every three Black students who graduated in five years. This could possibly be linked to language problems, among other factors. Many students are schooled in their home language, implying that non-English speaking students are to attend lectures, read and study in English. The learning environment in the a large number of schools is also not conducive for optimal preparation for Higher Education due to lack of qualified teachers and resources. Foxcroft and Stumpf (2005:7) researched the correlation between academic performance and second language and identified reasoning as a fundamental problem.

  Carroll (1993:634) adds to the notion expressed by Jensen (1973:264), that achievement is determined by mental processing of which reading and writing form an integral part. Floyd *et al.* (2003:155) found that language processing is important for maintaining Mathematical skills, whereas Van der Walt (2009:379) recognises the fact that only when students felt confident and proficient in a language would they be able to fully comprehend Mathematical structures. The 'word problem' in Mathematics also finds application in Physics and Chemistry which creates problems in all three the above disciplines. Harding (2009:357) researched the influence of language on Mathematical modelling and found the relation indicative. Matoti and Lekhu (2008:128) elaborate on the different meanings of terminology and that students find the switching of codes from home language to scientific discourse to be problematic. The latter is problematic for students from the indigenous African home language group and to a lesser extent for the Afrikaans group, probably due to the historic existence of a better learning environment in Afrikaans schools.

- Finally, ethnic grouping within the biographical profile of the sample show a significant correlation with university performance. A high proportion of Black students are placed in the '*high risk*' category, compared to White, Coloured and Indian students (cf. Table 6.8). Ethnic grouping is highly (but not perfectly) correlated with home language in South Africa, with the majority of African language speakers being Black, and the majority of White students speaking either English or Afrikaans. The historic distribution of resources and opportunities are still creating discrepancies between schools with particular ethnic character where schools in Black communities have lesser ability to provide prepared students to Higher Education.

ii) To examine the predictive value of school performance (total Grade 12-score) with regard to success in first-year Science modules.

- Admission of first-year students has been based on school results only (M-score [2006 to 2008] and APS [2009] in Table 3.3) for many years. Academic aptitude and competencies were previously regarded as a sufficient reflection of quality schooling (cf. Section 3.4) and assessed academic proficiency or prior learning (cf. Section 6.4). Research conducted by Engelbrecht *et al*. (2009:294 in Figure 3.8) indicate that there is a decline in factual knowledge. This is also confirmed by this study (Figure 3.7) which implicates a review of first-year curriculum in specifically fundamental Science modules.

  A statistical analysis of M-score and APS (2009), confirmed that across the four cohorts, Grade 12-performance differentiated significantly between *'pass'*, *'risk'* and *'high risk'* categories, especially in 2007, 2008 and 2009. In comparison with the M-score, the APS (used from 2009) show weaker predictive power regarding university performance (cf. Table 6.9). Application of the global Grade 12-score as an admission instrument together with other instruments is advocated by Foxcroft and Stumpf (2005:7-10) as well as Foxcroft (2009).

iii) To correlate school performance in individual subjects (i.e. Mathematics, Physical Science and English) with first-year performance in Science modules.

- Students' Grade 12 English language results correlate significantly and positively with university performance in 2006 and 2007 (cf. Table 6.5). Adetula (1990:352) found that deficits in English linguistic skills impede Mathematics performance. Students in Science programmes struggle to achieve at university in part because of relatively poorly developed English skills and competencies.

- Students' Grade 12 Mathematics results correlate significantly and positively with university performance. High school Mathematics can be seen as a "rite of passage" and serve as a 'gateway' to further studies in Science (Steen 2006:12 and Khan 2004:155). An aspect of concern is that students' Grade 12-results for Mathematics appear to be inflated (cf. SAIRR 2009b; Nel and Kistner 2009:968). Nevertheless, the Grade 12 Mathematics results for the 2006 to 2009 cohorts show significant correlations with performance and will most likely remain one of the major indicators of university performance.
- Students' Grade 12 Physical Science results do not correlate significantly with academic performance at university level in 2006, 2007 and 2008. However, a significant and positive correlation is observed in 2009. Nel and Kistner (2009:968) indicate that like the Grade 12 Mathematical results, the Grade 12 Physical Science results of students may be inflated.

iv) To examine the predictive value of an independent scholastic proficiency test, namely the Stellenbosch University Access Test, with regard to success in first-year Science modules.

This research probed alternative instruments to determine the proficiency level of entering students. For the 2008 and 2009 cohorts, the Stellenbosch University Access Tests in Mathematics and Physical Science are used (cf. Section 5.6.3).

- In a first analysis, the Stellenbosch University Mathematics Access Test reveal no significant correlation with academic performance at university level for the 2008 and 2009 groups respectively (cf. Table 6.13). A significant correlation is indicated however, when the two groups are combined. The Mathematics Access Test provide useful information that predicted overall university performance, as verified by Nel and Kistner (2009:953-973).
- Similarly, the Stellenbosch University Physical Science Access Test reveal no significant correlation with academic performance at university level for the 2008 and 2009 groups respectively (cf. Table 6.14). As found with the Mathematics Test results, there is a significant correlation when the two groups are calculated as one group. The Physical Science Access Test provide useful information to predicted overall university performance. Nel and Kistner (2009:953-973) proposed that these results be regarded as a yardstick for benchmarking.

In an analysis of academic performance in university modules with regard to overall Grade 12-results (M-score/APS) and the two Stellenbosch University tests, in Science disciplines (Mathematics, Chemistry and Physics), the hierarchical multiple regression reveal the following:

- For Mathematics 1A, the M-score (2008) shows 12.4% of the explained variance with the APS (2009) indicating only 5.9%. When adding the two tests results, the 2009 proportion of explained variance increased with 17.2%, providing a total explained variance of 23.1% in 2009 (in comparison to 18.9% in 2008). Over and above the Grade 12-results, the Stellenbosch University results therefore provide substantial predictive value, as was found by Nel and Kistner (2009:953-973).

  In specialised Mathematics (1C), in 2008 (cf. Tables 6.15, 6.16, 6.19 and 6.20), the variance explained as a result of the M-score (22.1%) is complemented with another 14.1% from the Stellenbosch University tests. The results indicate less explained variance predicted for 2009 (a total of 21.0%) (cf. Tables 6.17, 6.18, 6.21 and 6.22).

  In all four Mathematics groups, the correlation of university results are best reflected by the Stellenbosch University Mathematics Test, and then only in the overall score. The National Benchmark Test should hopefully indicate a similar pattern and could be used as a diagnostic instrument for entering students. Huysamen (2007:66) and Zwick (2007:5) reiterated the worldwide concern regarding the under-preparedness for university Mathematics, which would be problematic for South Africa, given the language proficiency and teacher problems.

- For Chemistry at first-year level, the M-score in 2008 indicate 28.4% and 25.3% of the explained variance in the two respective modules (cf. Tables 6.24, 6.25, 6.28 and 6.29). The predictive contribution of the two Stellenbosch University Access Tests reveal better predictability in 2009 (cf. Tables 6.26 and 6.27). The Stellenbosch University Access Test contribute significantly to the predictability of performance in Chemistry in the first year in 2008 (approximately 30% and almost 26% in 2009) (cf. Table 6.27 and 6.28). Specialised Chemistry (Chemistry 1C) has no significant correlation with APS or the Access Test indicating university performance.

Given the significant correlation of the four Chemistry groups, the overall Grade 12-results (M-score and APS) proved best in predicting university results, followed by the Stellenbosch University Physical Science Test. The so-called "Science lag" (The Star 10 March 2007:25) and the phenomenon of high failure of first-year students (Beeld 09 April 2009:6) are discussed by faculty management nationally. The fact that only 20% of Science teachers have university training (Naidoo and Lewin 1998:740) might be blamed for this performance.

- In Physics modules at first-year level, the performance is predicted significantly by the M-score in 2008 for Physics 1C, and by the two Stellenbosch University Access Tests in 2009 (cf. Tables 6.36 and 6.37). There is no significant correlation between M-score and performance in main stream Physics in the first year in 2008, and only significant indication from the two Stellenbosch University Access Tests (cf. Tables 6.32, 6.33). Indicators of the APS are few in 2009, but the results of the two Stellenbosch University Access Tests reveal better predictability with almost 36% of the performance in main stream Physics being predicted in the first year (cf. Tables 6.34 and 6.35).

  There is a significant correlation of university results with performance in Physics, as indicated by the Stellenbosch University Physical Science Test, which provide better results than the Stellenbosch University Mathematics Test regarding the overall score.

v) To examine the predictive value of personality traits, as measured by the Basic Traits Inventory and the Study Orientation in Mathematics Tertiary, with regard to success in first-year Science modules.

The findings of the empirical tests provide rather predictable results. Personality, motivation, interest, anxiety and self-esteem had all been identified as factors to influence academic achievement (cf. Section 4.3.6), with Linnenbrink and Pintrich (2002:317) adding stability, effort, skills and talent to the list of attributes for success.

- Results from the Basic Traits Inventory indicate that there is a significant correlation of conscientiousness with academic success (cf. Table 6.41). This is expected and in accordance with the literature review on this instrument. McCrae and Costa (1991:97), De Bruin (2000:88) and Taylor and De Bruin (2004:11-36) identified openness to experience, conscientiousness and extroversion to be well correlated with academic success.

- Similarly, the results of the Study Orientation in Mathematics Tertiary indicate significant correlation to academic success (cf. Tables 6.42 and 6.43). However, Visser (1988:38) expresses concern about the fact that individuals felt intimidated and anxious about Mathematics. Eiselen (2006:69) elaborated on the contagious effect of anxiety on performance in Physics and Chemistry, whereas Maree (2005:86-92) provided evidence that the Study Orientation in Mathematics Tertiary indicated diagnostic areas for future support.

The deductions as discussed above considered three categories, namely, those generally applicable to Higher Education, those related to teaching in Science specifically, and those focusing on student success in the first year (mainly the empirical research). The deductions highlight poor fit amongst the Higher Education sector in general, demands of universities in respect of Science, and the competencies of entering students. This disjuncture ('gap') is presented in Figure 7.1. The figure illustrates the three key elements that show attributes deemed to be integral to the development of a framework for placement. All the shapes have perforated edges, allowing for the free movement of influences from within and from the outside. The smaller pentagon, on the left, represents first-year students transferring from school (outside the Higher Education sector), on track to enter the university. The larger pentagon, on the right, represents the university with the apex where students' first entry point would be. Indicative of the above presentation are the two "apexes" (from the two pentagon shapes) not 'fitting' into each other. The open area between the two apex shapes resembles the 'gap' between school and university.

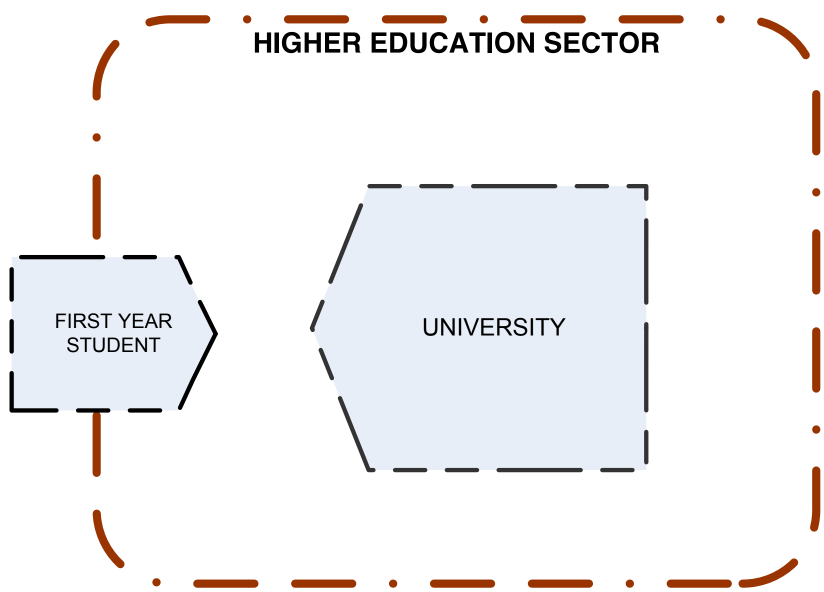


***Figure 7.1*** **The core components within the Higher Education sector**

i) The first component represents the Higher Education sector, which in turn, represents authorities, as well as international and national stakeholders. The stakeholders include all institutions, potential students, related industries and the general society.

ii) The second component included in the above sector, represents universities. The institutional culture, student support, nature of teaching and learning and physical location are unique features of every institution.

iii) The third component is the entering student (specifically first-year students enrolling for Science-related programmes). These students enter the sector from a specific school context, each with specific characteristics attributed to their cognitive and non-cognitive abilities, and profiles of all individual students.

The deductions formulated from literature and empirical research eventually guide the compilation of foundational principles from which the framework for the placement of first-year students are derived.

## 7.3 THE FOUNDATIONAL PRINCIPLES DERIVED FROM THE DEDUCTIONS

Table 7.1 presents in tabular format the foundational principles for the successful implementation of the framework for the placement of Science students. The principles are aligned to the deductions formulated from Section 7.2 and guide the activation and implementation of the framework.

**Table 7.1** ***Foundational Principles for the implementation of the Framework for Placement***

| Deductions | Foundational principles |
|---|---|
| First-year Science students perform unsatisfactorily in first-year Mathematics, Physics and Chemistry (cf. Section 7.2.3).<br>The lack of qualified and experienced teachers in Science modules impedes student success. (cf. Section 7.2.2)<br>The new curriculum: challenges with outcomes-based education; inadequate training; and all students being obliged to study Mathematics reflect some of the problems in the schooling system (cf. Section 7.2.2).<br>It has been demonstrated that first-year students (with a few exceptions) are not adequately prepared for the challenges of university Mathematics and Science (cf. Section 7.2.3).<br>Teachers are no longer obliged to cover the entire curriculum (cf. Section 7.2.3). | The South African school system is found lacking. It is unlikely to change in the near future and is unlikely to provide adequate numbers of suitably equipped first-year Science students to universities within the next few years. |

| | |
|---|---|
| Institutions had to design extended programmes to provide opportunities to students with potential (cf. Section 7.2.1). | |
| Students who meet minimum requirements for admission to Science programmes do not necessarily have the aptitude and cognitive potential to be successful (cf. Section 7.2.2).<br>Standardised assessment of cognitive and non-cognitive attributes of first year students can be applied to the advantage of individual students and the institution (cf. Section 7.2.2).<br>Science students might claim to be interested in Science, but may be lacking with respect to preparedness or with respect to the traits of conscientiousness and self-directedness (cf. Section 7.2.2).<br>Assessment should take place early in the year to allow for meaningful intervention (cf. Section 7.2.3). | Universities should determine/ evaluate the strengths and weaknesses and learning readiness of every individual student to ensure that quality learning takes place |
| First-year students need time and guidance to adapt and adjust to the university environment (cf. Section 7.2.3).<br>First-year students need to be informed about various policies applicable to them, (cf. Section 7.2.1).<br>Entering first-year students must take cognisance of policies related to their academic progress. Students often have no concept of what will happen when they fail (cf. Section 7.2.2).<br>Students rarely fail at school, resulting in students being falsely confident in their ability to succeed and unaware of the consequences of failing (cf. Section 7.2.3).<br>The curricula of programmes in Natural and Agricultural Science, Engineering and Health Sciences include generic fundamental components, such as Mathematics, Physics and Chemistry (cf. Section 7.2.1).<br>Students have limited opportunities to change or articulate from one programme to another (cf. Section 7.2.2). A generic first semester will allow for such changes to take place.. | Universities should provide planned and structured "First-year Experience" programmes that include orientation, curricular, co-curricular, support and transition components during the first year of study. |
| A well-planned academic orientation programme presented by faculty lecturers will help students to adjust to the university environment (cf. Section 7.2.2).<br>Lecturers should start their lecturing at the appropriate level, which implies knowledge of the school curriculum. Baseline knowledge levels of beginning students should be determined and course content should be designed to flow naturally from the baseline (cf. Section 7.2.3). | First-year Science lecturers should be content specialists and knowledgeable with respect to the teaching of beginning students. |

| | |
|---|---|
| Lecturers of first year students should be trained in the teaching methodologies of their discipline (cf. Section 7.2.3).<br>Institutional audits (cf. Section 2.5), performance management of staff, and enrolment management of students (cf. Section 2.4), create a bureaucracy that challenges academia (cf. Section 7.2.1)<br>Lecturers must accept the challenges presented by under-prepared students (cf. Section 7.2.3). | |
| First-year students need to acquire academic language competencies to be able to succeed in their studies. (cf. Section 7.2.2). Similarly, first year students need to acquire computer skills to be able to succeed (cf. Section 7.2.2).<br>Early contact during registration and orientation with lecturers may help students to bridge the real and imagined world of academia (cf. Section 7.2.2).<br>Students may benefit from a structured and extended curriculum, where competencies with respect to writing and study skills are explicitly addressed (cf. Section 7.2.3).<br>First-year students in Science modules often do not have explicit career related goals. This may be a consequence of inadequate career counselling at school (cf. Section 7.2.2).<br>Students should be aware of places/units/centres that can give support when problems arise (cf. Section 7.2.2).<br>Students can benefit from structured career development interventions that are integrated into the curriculum (cf. Section 7.2.1). | The first-year Science curriculum at universities should allow for the inclusion of English language proficiency, computer literacy, academic literacy and career counselling as formal course requirements |
| Students may benefit from systematic contact with lecturers who serve as academic mentors and advisors. Such advisors would be well-placed to advise students when they appear to be at risk to fail modules or actually fail modules.<br>Current programmes in Sciences are specialised, and students often have misconceptions of what their career decisions will entail (cf. Section 7.2.2). Academic mentors can advise students on career options and how this relate to their choice of modules. | First-year Science students should be allocated to an academic advisor who is a lecturer in their field of study and who will mentor them throughout their studies. |

| | |
|---|---|
| Parents or caregivers of first-year students contribute to their success. First-generation students appear to be at risk and are in need of additional support (cf. Section 7.2.2).<br>Wider participation in Higher Education means that increasing numbers of students with a need for economic, social and financial support enter universities (cf. Section 7.2.1).<br>Unsuccessful students have a financial impact on their families, as debts and low self-esteem are difficult consequences to manage (cf. Section 7.2.2). | First-year experience programmes should include orientation of and communication to parents/caregivers, maintain support structures during transition, and share responsibilities. |
| Recruitment of talented students is of utmost importance for the sustainable intake and growth of Science at a university (cf. Section 7.2.1)<br>An insufficient number of teachers contribute to the already limited pool of scarce skills (e.g. Engineers, Scientists, Medical practitioners and Teachers) (cf. Section 7.2.1)<br>Policy and curriculum changes have contributed to teachers who are under qualified with respect to the teaching of Science (cf. Section 7.2.1).<br>Teachers are important recruitment officers for Science studies and have the opportunity to influence careers and decisions pertaining to future study by cultivating and nurturing Science from an early age (cf. Section 7.2.2). | Science faculties at universities are involved in and acknowledge the role that Science teachers play in cultivating and recruiting potential Science students. |

In summary, the foundational principles upon which the framework for the placement of students will be based are clustered in six groups (cf. Section 4.6.4). The six groups are clustered as follows:

- The school: The literature review suggests that the South African schooling system will not change in the near future and will not be able to produce adequate numbers of well-equipped first-year Science students to universities within the next few years. Science faculties should be involved in and should acknowledge the role that Science teachers play in cultivating and recruiting of potential Science students.
- The assessment of the first-year student: Universities should evaluate the strengths and weaknesses (cognitive and non-cognitive) and learning readiness of individual students to ensure that quality learning takes place. Universities should be able to diagnose any academic needs and address these with expert services.

- The first-year Science curriculum: Universities should allow for an initial generic phase with a semester covering Fundamental Mathematics, Fundamental Physics and Fundamental Chemistry. All students should follow the generic curriculum. After the completion of the generic or introductory semester, students should be able to articulate into specialised Science, Engineering and related programmes. A generic phase will allow students to gain greater clarity with respect to their interests, their career goals, their strengths and weaknesses, and different routes of specialization. Ultimately, it is expected that a generic phase will allow students to make more informed choices with respect to major subjects and programmes of specialisation. In turn, after completion of a generic phase faculties of Science will be in a better position to advise students with respect to the best degree or diploma programmes.
- First-year Science lecturers: Lecturers should be knowledgeable and experienced and should be qualified to teach an appropriate methodology that includes the content and skills of the fundamental curriculum. Lecturers for first year students should be carefully selected and receive specialized training with respect to the teaching of beginning students.
- The first-year support structures: The first-year Science curriculum should provide for the inclusion of English language proficiency, computer literacy, academic literacy and career counselling. First-year Science students should ideally be allocated to an academic advisor who could be a lecturer or tutor in their field of study and will mentor them throughout their studies. Ideally, Science faculties should have dedicated and specialist academic counsellors that can collaborate with the faculty and advisors with respect to the placement of students after the generic phase had been completed.
- The "First-Year Experience": Universities should provide planned and structured "First-year Experience" programmes that include orientation, curricular, co-curricular, support and transition components during the first year of study. These programmes should include orientation of and communication to parents/caregivers, maintain support structures during transition, and share responsibilities.

To conclude, the literature and empirical findings revealed that the above foundational principles (placed in six categories) are important in facilitating the success of first-year Science students. The implications of these six foundational principles can be visually presented as a hexagon shape that closes the gap between the pentagon presenting the first-year student and the pentagon presenting the university (compare Figures 7.1 and 7.2).

The interfaces of the placement hexagon in Figure 7.2 with the first-year student and the university, respectively, hold important implications for achieving fit between the student and the university environment. The apex of the university pentagon mirrors the apex of the first-year student pentagon, which symbolizes the lack of fit between student and university. However, by inserting the placement hexagon between the two pentagons a seamless fit between student and university can be achieved.

The 'placement' hexagon changes the 'front door' of the university from the 'current interface' to a 'transformed interface'. The hexagon fits neatly into the university pentagon and extends beyond the apex of the first-year student pentagon. This indicates that an appropriate placement mechanism can facilitate the achievement of student fit and adjustment. The placement hexagon indicates that the university is transforming curriculum, processes, support and lecturers to accommodate the newly entering students. The framework for placement reshapes the university and embraces the first-year student.

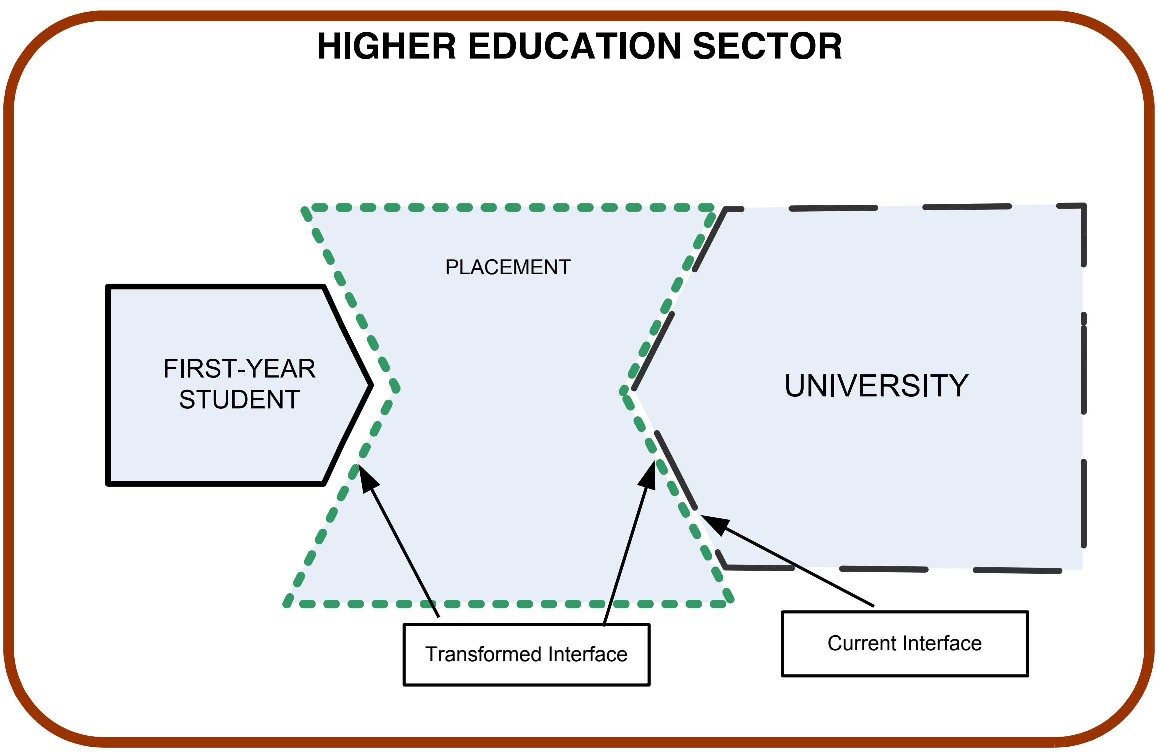


***Figure 7.2*** **Bridging the 'gap' between first-year students and the institution**

## 7.4 DEVELOPMENT OF A FRAMEWORK FOR PLACEMENT OF FIRST-YEAR STUDENTS IN SCIENCE PROGRAMMES

As yet, the concept of 'placement' after admission has not been fully endorsed by South African Higher Education role players (see Section 1.5 for a full discussion). Placement of students is the process of placing already admitted students in an academic programme or stream where their student profiles match the performance profile of success in the specific academic programme. Thus, placement is a post-admission process, in order to enhance academic success. The proposed framework aspires to encourage the consideration of placement strategies by universities, with specific reference to Science-related programmes.

### 7.4.1 The purpose of a framework for placement

The purpose of the framework for placement is to optimise student success in Science-related university programmes. The framework proposes mechanisms to prevent the first-year student failure in Science modules and programmes.

### 7.4.2 Process followed in developing the framework

In this section the process followed in designing the framework, is highlighted.

Step 1: A review of other theoretical frameworks

The proposed framework is based on exemplary frameworks in the Higher Education environment. In available literature studies no framework for the placement of first-year students in Science programmes could be located, but four other frameworks influenced the researcher's thinking in respect of the development of this particular framework.

Gravett (1993:141-152) developed a framework that aims to facilitate and integrate optimal student learning, lecturer teaching and the professional development of university teachers. In the framework developed by Greyling (1993:233-246) the emphasis falls on distance education programmes at residential universities. De Bruin (2000:197-228) employed a literature overview and empirical study as the basis of a framework that aims to develop self-directedness among university students. Finally, Gous (2002:297-335) compiled a framework for developing an ideal organisational climate and culture within a Higher Education institution.

The four abovementioned frameworks (Gravett, Greyling, De Bruin and Gous) were all applied within the university context and contribute meaningfully to the conceptualisation of this study's proposed framework.

Step 2: Deductions made in respect of the findings
Deductions were derived from the literature and empirical findings on Higher Education, Science in institutions and first-year students (cf. Section 7.2).

Step 3: Deriving foundational principles from the deductions
Foundational principles were clustered in six categories to indicate the essence of a framework for placement for first-year students in Science programmes.

Step 4: Guidelines for implementing the framework
Guidelines are the rules that can be used to help one make a decision or form an opinion. In the context of compiling the framework the guidelines indicate the prescriptions for action.

Step 5: Required conditions for implementing the guidelines
Conditions are the circumstances that affects the action. In this specific context, the guidelines for implementation (captured in Step 4) rely on the pre-conditions that had been identified to enable implementation. The conditions influence the actual practical execution of the framework and reflects the final phase of the proposed framework.

## 7.5 A FRAMEWORK FOR THE PLACEMENT OF FIRST-YEAR SCIENCE STUDENTS

A framework for the placement of students is visually presented in Figure 7.3. As outlined in the research objective (cf. Sections 5.3 and 7.2.1), there is a need for a framework that can serve as a 'road map' for the placement of university students in Science learning programmes. The proposed framework constitutes a cyclical, conceptual pattern that is based on theoretical (literature-derived) and empirical deductions. The guidelines for implementing the framework and enabling conditions will be discussed subsequently.

The lack of a placement framework currently limits research on admission, selection and placement procedures of entering first-year students. By means of the framework effective and efficient placement of first-year Science students may be enhanced. The guidelines and enabling conditions will guide practices in this regard.

### 7.5.1 Diagrammatic presentation of the framework for placement

Figure 7.1 depicts a 'gap' between first-year students and the institution. This gap represents a mismatch between students expectations and levels of preparedness on the one hand, and Science faculties' expectations and requirements on the other hand. In Figure 7.2 this gap is 'bridged' by the 'placement hexagon'. The hexagon enables the two incompatible shapes, representing students and the institution, to link with each other. Figure 7.3 presents a more complete representation of the framework for the placement of Science first-year students. In this figure placement is presented as a partial solution to the problem of unsatisfactory performance of first year students. The figure contains (a) the basic elements of the placement framework in the shape of the hexagon, (b) guidelines for the implementation of the framework, and (c) conditions on which the successful application of the framework depends. outcome and consolidation of the 'gap' and the 'hexagon' in a broader context:

Figure 7.3 indicates the initial problem as the high number of first-year students that fail in fundamental Science modules (cf. Table 2.5 p.61; Engelbrecht *et al.* 2009, UJ 2008b and 2009c; Maree 2009). A partial solution to the problem is proposed in the form of post-admission placement of first-year students. The placement framework is based on deductions of a comprehensive literature review and empirical research with respect to three categories, namely the broader Higher Education context, faculties of Science in particular, and first-year students. With respect to the Higher Education context the deductions focus on policy directives and current challenges regarding student throughput and retention. The second category focuses on challenges that Science faculties have to deal with. For the most part these challenges are attributable to mismatches of the school curriculum and student preparedness on the one hand, and the university curriculum and requirements of students on the other hand. The final category focuses on the first-year student in fundamental Science modules and addresses individual differences with respect to academic aptitude and learner readiness. The funnel shape indicates that the placement framework is extracted from the deductions related to these three categories.

The funnel leads to the six foundational principles that underlie the placement framework. These principles are (a) a recognition that schools may not adequately prepare learners for the challenges of university education, (b) the need for an extended curriculum with a generic first semester, (c) the need for dedicated lecturers of first-year students that are content and didactic experts, (d) the need of continuous student support in the form of mentoring, guidance and counseling, (e) the need for comprehensive assessment of students' cognitive and non-cognitive attributes that relate to academic performance, and (f) the need of an integrated First Year Experience programme that facilitates the adjustment of first-year students into the university environment. The foundational principles serve as a ‘bridge’ that allows first-year students to enter the university. The foundational principles fill the ‘gap’ between the school and Higher Education.

Figure 7.3 also highlights guidelines for the successful implementation of the framework. These guidelines are (a) the establishment of an enrollment centre, (b) the provision of extended degree programme with a generic component in the first semester of the first year, (c) the comprehensive assessment of students with respect to academic aptitude, learner readiness, and relevant non-cognitive attributes such as conscientiousness and motivation, and (d) the implementation of a specialized teaching and learning strategy. These guidelines are discussed in more detail in paragraph 7.5.3.

In addition to the guidelines, Figure 7.3 also reflects six conditions that have to be met for the framework to be successfully applied. These conditions include (a) support from Science and related faculties across the board, (b) institutional support, (c) faculty ownership of the framework, (d) enrollment management, (e) strategic provision of services, and (f) continuous research. These conditions are discussed in more detail in paragraph 7.5.4.

Finally, the rightmost part of Figure 7.3 indicates the dynamic nature of the framework for placement. After each cycle of placement the feedback is used to revise, improve and grow the framework to better meet the needs of students and the institution.

Jointly, the foundational principles, guidelines and conditions for implementation, constitute the framework for placement. This framework can serve as a point of departure for the placement of first-year students in Science programmes.

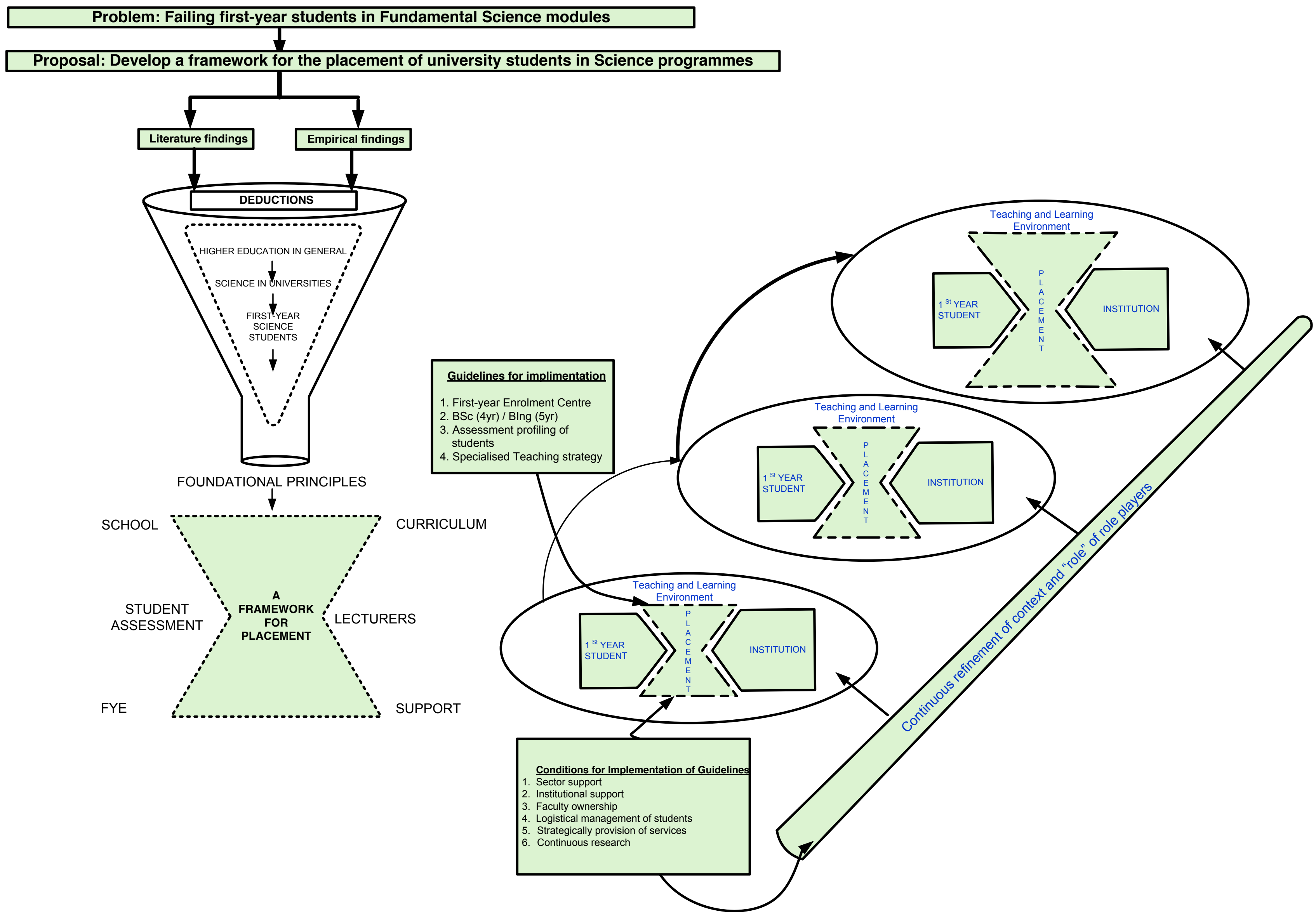


*Figure 7.3* **A framework for the placement of students in Science programmes**

### 7.5.2 Guidelines for implementation of the framework for placement

In this section guidelines for the successful implementation of the framework are presented. Such guidelines direct actions with respect to the implementation of the framework. Four guidelines that are deemed essential are proposed below.

#### *7.5.2.1 The Establishment of a First-Year Enrolment Centre*

This investigation proposes that Enrolment Management of first-year students should ideally reside within a centralised institutional Enrolment Centre. Such a centre should manage core processes such as recruitment, applications, admissions and registrations, in collaboration with faculties, support divisions, finance departments and other stakeholders (cf. Section 2.4). It should also coordinate the tracking of students, research on performance trends and throughput as well as enrolment and capping of student numbers.

From the literature review, a tension between recruiting the 'right' students and increasing throughput becomes evident (Scott 2009, Foxcroft 2009, Yeld 2009). Enrolment does not form part of the daily activities of ordinary administrators, lecturers and managers in an institution and will be addressed only occasionally at specific intervals during the year. Lecturing staff should ideally be more involved in recruitment and supervision of entering students, in order to get acquainted with the essence of the "raw material" entering the academic world (cf. Section 2.6.2).

Enrolment Management is important to the reputation and status of every university and should be acknowledged as such. A major concern is the fact that students perform well at school with little effort and have similar expectations of university studies. Another function of such a centre could possibly be to coordinate and manage the academic orientation of first-year students. Academic orientation should be compulsory and credit-bearing if it is to succeed. Ideally, lecturing staff should be involved in this process and get acquainted with their students as soon as possible. Researchers (cf. Section 3.4.3) caution institutions that having "…enthusiastic, friendly and competent administrators…" meeting with students have little value. Academic staff should rather be engaging with their students. Programme-specific orientation such as in Science could involve laboratory safety courses, computer proficiency testing, study skills, writing of practical reports, and other skills required to manage studies. The involvement of parents has also proved to be very successful (cf. Section 3.4.3).

The provision of information and all the special services provided to first-year students could form part of the functions of such a centre. In the proposed centre first-year students could be provided with career guidance and counselling within the domain of placement. The centre could coordinate institutional enrolment strategies and procedures and support students, staff and parents. A special division could also oversee and take care of special needs of international first-year students.

The First-Year Enrolment Centre should be an academic centre where first-year students, lecturers and support staff collaborate. It should not be an administrative office that handles applications and executes policies constituted elsewhere. The centre should inform the university on the latest applicable trends, perform research and be the niche where inter-disciplinary activities and decisions are generated to ensure that successful first-year students continue to become highly successful postgraduate students.

#### *7.5.2.2 Design of a four-year (BSc) and five-year (BIng) degree qualification*

In order to realise the full potential of placement, there is a need for additional time for the university to engage with first-year students. Both students, and the institution, need time to adapt to each other. In view of the literature on drop-out (cf. Section 2.3) most students in Science programmes take longer than the prescribed three years to graduate in the three-year time-period. Similarly, very few students graduate in Engineering within the prescribed four years. It is important, however, that the current offering (three-year BSc and four-year BIng), remains as the path of acceleration for the ‘ready’ and self-directed students.

It is proposed that the BSc becomes a four-year degree option. The four-year option becomes the default (cf. Section 3.4.3). The four-year BIng degree can also be extended to a formal five-year degree as a default option. The condition for the BSc (IV-option) and BIng (V-option) is that it should consist of a well planned and structured curriculum. Purely extending and adding foundational provision will not ensure student success. The institution must also change the curriculum and its execution.

Students and lecturers experience a ‘gap’ between school and university. This additional year can be perceived as a “gap-year” – not taking a ‘gap’ but “bridging the gap”. The proposed structure considers the deficits students have upon entering Higher Education regarding language, Mathematics and Physical Science, career counselling and academic literacy.

The structure of the four/five-year option will provide students with sufficient time to adjust and also afford the institution sufficient time to analyse and profile students, in order to provide assistance and support where required. Firstly, the Science, Health Sciences and Engineering students will apply by indicating a particular Science programme, and if adhering to admission requirements they will be admitted to Science programmes that could be managed as a ‘college’. Secondly, all the students in the ‘college’ will have a generic semester programme and follow the same curriculum.

The students will all register for the generic first semester where they will follow the Fundamental Mathematics, Fundamental Physics and Fundamental Chemistry modules. These three modules will be complemented with a module in English as well as an academic literacy and a computer literacy module. During this semester the students will be assessed and profiled and will be provided with personal and career counselling. After successful completion of the first semester the students will be placed in suitable modules within the programme of their choice. However, almost all of the programmes require the Fundamental Science modules which implicate that they will continue with Mathematics, Physics and Chemistry for the second semester with elective modules such as Biology, Geology, Geography, Engineering graphics and Applied Mathematics. The pace is slow and only 50% of the first semester (current main stream) content will be covered with sufficient support and guidance.

In the first semester of the second year (the actual third semester), the remaining 50% of the entry level module will be presented and after this semester students would have accumulated the same credits as in the first semester of the current main stream first year. The students would thus have been engaging with the complex content for three semesters and they would have started at the core needed to pass university level Science. The second semester of the second year would be an adjusted format of the current second semester content (of the first year) implicating that it took students two years to cover the current first year curriculum but in a planned and structured programme. It is presumed that they would be sufficiently equipped to then register for main stream second, third and fourth year curriculum where applicable.

During the additional time students will become acquainted with the Higher Education culture and work ethics, in other words “bridging the gap”. Unsuccessful students may be placed in other fields or programmes (ranging from degree to diploma) with less difficulty than is currently the case.

#### *7.5.2.3 Assessment of first-year students for profiling*

In order to realise the full potential of placement, institutions need to assess all entering students with respect to factors that may impact on their academic achievement. During the generic first semester, institutions will be able to assess the potential as well as cognitive and non-cognitive attributes of every first-year student. Early diagnosis of any potential weaknesses will allow for in-time support, while expert counselling will enable students to make informed decisions on future career paths. Placement will result in 'fitting' students in programmes where they can be successful. Selection of majors, distinction between degree and diploma and articulation possibilities will all be available, based on student profiles.

Foxcroft (2009) provides feedback on the proposed profiling. The graph in Figure 7.4 indicates the profile of the successful ('*pass*') student (with the blue line graph) and the profile of the unsuccessful ('*high risk*') student (with the red line graph). The two graphs were compiled from actual data collected within the sample of participants of this investigation. Plotting every student against this profile (every programme in the institution must determine the profile of the successful student) will provide an indication of the risk involved for the student. Figure 7.5 presents examples of measurements that may be included in the profile.

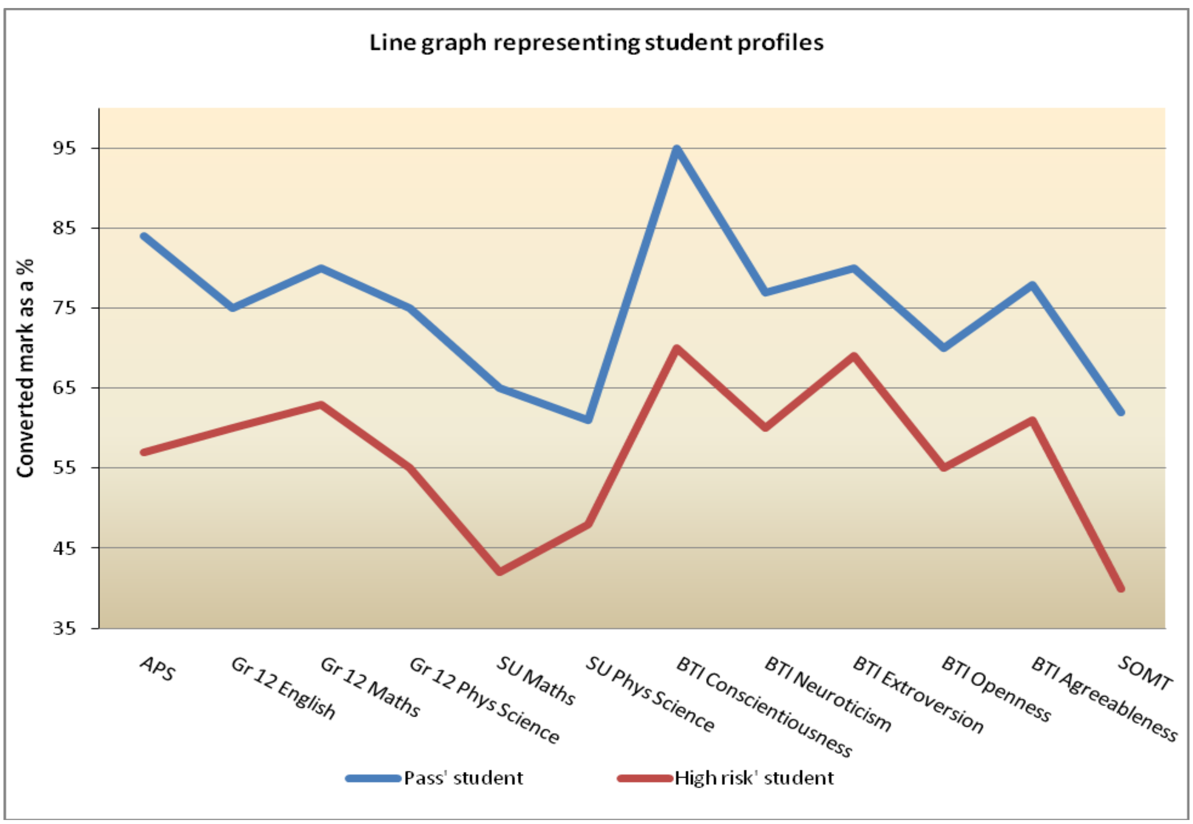


***Figure 7.4*** **First-year student profile** *(Adapted from Foxcroft 2009)*

In Figure 7.4, the profile of a successful ('pass') student and a unsuccessful ('high risk') student are presented, with an initial profile of a new entering student. This will enable the counsellor and lecturers to make an informed decision for placement of the student. During the first semester, continuous profiling, with assessment of content, skills and growth in specific areas can inform decisions to be made after the first semester. Knowing students' potential, personalities, interest, locus of control, self-directedness and anxiety levels takes time. This knowledge can now be acquired in the generic first semester and during academic orientation.

*7.5.2.4 First-year teaching and learning strategy*

The emphasis on the adjustment and challenges first-year students face is mostly precipitated during formal lectures. Gardner (cf. Section 3.4.3) explains the dynamics of a lecture where actual contact between student and institution (personified by the lecturer) takes place. New students are confronted with content of new disciplines, and may discover that their self-assessment do not match the reality at university level. It is proposed that institutions carefully design a 'First-year teaching strategy'. Such a strategy should provide guidelines, steer teaching and support for lecturers and provide a forum where first-year lecturers are able to share best practices (cf. Section 4.6). The strategy should also include coordinated provisional support for first-year students. The appointment of additional and suitably qualified staff (specialised in teaching first-year students), budgeting for additional services, and division into smaller student groups are some of the important issues to be contained in such a strategy. Successful placement will attempt to place students in the most suitable programme. Therefore, the most suitable lecturers should be appointed to teach and inspire students (cf. Section 4.6).

Lecturers that teach the first-year curriculum cultivate the postgraduate class of the future. Careful staff selection will include confident staff who teach with passion. Staff with appropriate education qualifications and interest will complement the specialised methodology to commence with teaching the fundamental Science concepts and providing higher level students. The strategy should provide opportunities for the alignment of curriculum content (e.g. when Physics will require which topics in Mathematics). The strategy could possibly also propose a coordinated assessment system for first-year students within a programme (cf. Section 2.6.1 and 4.6). The alignment of theory and practicals within modules such as Physics and Chemistry could also be addressed to apply theoretical concepts and alignment with other disciplines (e.g. Biochemistry, Geology and Applied Mathematics).

## 7.6 CONDITIONS FOR THE IMPLEMENTATION OF THE FRAMEWORK FOR PLACEMENT

Based on available literature and findings in this study, some pre-conditions to enable the implementation of the proposed framework were identified. The proposed framework can be implemented if the enabling conditions below are met.

### 7.6.1 Sectorial support

The Higher Education Science fraternity should embrace the proposed four-year BSc or Diploma option (or the five-year option for Engineering). If Higher Education authorities and other universities do not accept the principle of an extended degree with a generic component in the first year, students will enroll at institutions where they have a 'short cut' option. Given the profile of first-year students under investigation, all institutions will be obliged to determine capacity for accelerated and extended programme offerings. The Department of Higher Education and Training should support the extended degree or diploma options with legislation, and support the establishment of enrolment centres with funding, in order to provide institutions with the capacity to populate such centres. Student funding should improve, as the proposed structure strives to enhance throughput and student retention in the system.

### 7.6.2 Institutional support

Within every university, institutional management must support and provide faculties with quality staff, sufficient budgetary provision and status. Lecturers teaching and involved in the "First-Year Experience" programme should be selected carefully and trained to perform sophisticated lecturing duties that should not be regarded as remedial work. Entering students are future postgraduate students and all role players should embrace plans to recruit and retain students. As Science programmes usually have smaller student numbers compared to Commerce and Humanities, the support at Deans' level will ensure that the programme have a high status and attention.

Together with the constructive alignment of the curriculum an emphasis on compulsory lecture and tutor attendance, students will be gradually introduced to Higher Education. Quarterly progress reports to and even meetings with parents and sponsors (resembling parents' evenings at school) could probably assist with a shared responsibility to support the student. To provide the additional support and adjusted teaching strategy, institutional budgets should make provision for more staff. Psychometric testing also has financial implications for licensing and staff.

### 7.6.3 Faculty ownership

The support of faculty Deans, senior management (heads of schools and academic departments and programme managers) as well as other lecturing staff is of utmost importance to execute this proposal. Provision of extended programme types should not be regarded as the exception of the default three-year programme, labelling students and staff in the programme as special and easily identifiable. Ownership from all staff members in Science and related faculties will determine the success. A negotiated process of recognition of this process is advised. This is an academic matter, and foundational and academic support should be available to both staff and students. Experience has shown that outsourcing programmes, modules or management of academic support centres result in faculty staff being apathetic towards both students and programmes.

### 7.6.4 Logistical student management

The placement would require knowledge of the prospective student and of the chosen programme. The focus on first-year students will require budgeting, sufficient space and staff. The suggested First-year Enrolment centre could coordinate actions and interventions to provide students with the best support by a coordinated team. Constructive feedback to students on profiling, special timetabling to accommodate the majority of commuting students, and student housing and affairs should also be included.

### 7.6.5 Strategic provision of services and support

Specialised services to provide profiling, assessment and counselling of first-year students from pre-admission to placement will require psychometrists, educational and career psychologists. The strategic placement of students who fit into the programme profile requires decisions to be made by panels of experts, guided by the proposed first-year teaching and learning strategy. This strategy will also require specialised lecturers to manage the process. Faculties of Science should pursue an active involvement with schools and the school curriculum.

### 7.6.6 Continuous research

The scholarship of teaching and learning more about the disciplines, the students in the discipline and the methodology best suited to enhance student learning is of utmost importance. Continuous research of student progress, profiling and a growing knowledge base, will feed into the framework. Research on student profiles, quality ethos, placement and throughput will place the development and continuous reflection on best practices at the forefront of the academic status of research in institutions.

## 7.7 SYNTHESIS

In this chapter the literature and empirical deductions as contained in the foundational principles are presented. The proposed framework aligns the principles with the guidelines for implementation to enhance academic achievement in Science programmes. However, achievement and successful implementation of the framework depends on conditions of which some are provided here. In the final chapter, recommendations, limitations and proposals for future research will be discussed.

# CHAPTER 8

# DISCUSSION AND CONCLUSIONS

## 8.1 INTRODUCTION

This chapter contains the conclusions of the research. The previous chapter presented a framework for the placement of students in Science programmes. This chapter aligns the purpose of the study to the context of the study (Higher Education in South Africa, South African universities and the first-year Science student). Furthermore, the limitations of the study are highlighted, and proposals for further research within the field of education in Science will be made. The chapter concludes with practical implications of the research for Science education.

## 8.2 CONTEXT OF THE STUDY

This section provides an overview of the context, in order to emphasise the necessity of developing a theoretical framework for placement of first-year Science students.

### 8.2.1 Purpose of the study

The purpose of this study was to develop a framework for the placement of first-year university students in Science programmes. The framework will potentially be applied in programmes of fundamental Science disciplines, namely: Mathematics, Physics and Chemistry (cf. Section 5.3). Post-admission placement of first-year students (cf. Section 1.5) should alleviate the high failure and drop-out rate of students admitted to applicable academic fields, namely: Natural Science, Agricultural Science, Engineering, Technology and Health Science programmes. The purpose of the research unfolded in the subsidiary goals of the study, namely to review literature and conduct an empirical analysis of academic achievement.

In order to achieve the proposed goals, four chapters were dedicated to providing a background on academic achievement in Science. The purpose of chapter two was to determine indicators of academic achievement from the Higher Education policies, enrolment management strategies, and quality enhancement practices in learning programmes. The contribution from the review of Science learning programmes widened the lens on the Mathematics and Physical Science school curriculum specifically. In chapter three, the purpose was to determine indicators of academic achievement related to general mental ability. The focus of chapter four was to provide insight into the indicators of academic achievement related to non-cognitive attributes and factors. The subsidiary objectives of the empirical research study were to identify meaningful indicators of student success in fundamental Science modules, as described in chapters five and six.

The development and design of the framework (cf. Section 7.3) were based on deductions derived from the literature and the empirical findings at a sectorial level, the Sciences in general, and ultimately, at first-year student level.

### 8.2.2 The context of Higher Education in South Africa

Continuous changes in the South African school education system have influenced and will continue to impact on Higher Education. Post-1994 policies and approaches attempted to break down fragmented education sector barriers (divided on racial, language and socio-economic grounds) and to reform education into a single and simplified system (cf. Section 2.3). However, politicians used education as a transformational instrument, with every new government and new minister changing curriculum and assessment policies as well as the teaching approach. This volatile and turbulent environment resulted in teachers being more active in unions, rather than teaching in their class rooms (cf. Section 2.6). Prospective students left school with relatively good results, yet were under-prepared for Higher Education.

Higher Education reacted to changes in schools, and universities were inundated with applications, as increased opportunities were provided (cf. Section 2.3). This investigation focused on the transition and progression of learners from the formal school system to the Higher Education sector. The emphasis was on three core interdependent components that influenced the 'transfer' of learners from school to becoming university students, either directly or indirectly.

#### *8.2.2.1 The South African Higher Education sector*

The educational systems (school and Higher Education) were driven as a major thrust for transformation by political powers (cf. Sections 2.1 and 2.3). Reform in South Africa was focused on the fragmented and unequal education distribution prior to 1994. For the past 16 years, policies (cf. Section 2.3), processes (cf. Sections 2.4 and 2.5) and approaches (cf. section 2.6) provided direction. However, in many instances practices did not change. Research proved that first-year students failed and dropped out worldwide and not only in South Africa (long before 1994) (cf. Section 2.4). Student failure and drop-out have been more pertinent themes of conversation and research in South Africa during the past decade (cf. Section 2.4). Researchers made it clear that students have always had difficulty to pass

Mathematics at university (cf. Section 3.5). This investigation did not prove the above but attempted to propose a solution. What should institutions do?

The Higher Education policy framework (cf. Figure 2.3) provided a definite trajectory, with the following primary drivers that influence throughput and first-year student performance:

- The Higher Education landscape changed as a result of mergers and culminated in the reshaping of many universities (cf. Section 2.3 and Table 2.1) to create new 'types' of institutions. The two comprehensive South African universities (UJ and NMMU) experienced fierce merger dynamics (e.g. resistance, institutional cultural differences and duplication of management structures), as a result of traditional university and technology programmes combined within a single institution (cf. Section 2.3). However, five years have passed, and this investigation recognises the benefit of providing a comprehensive range of programmes (from diplomas to degrees) (cf. Section 2.4) within a single institution. Additional programmes with extended opportunities necessitate implementation of a framework for placement.
- Widened participation for specifically Black students was one of the primary drivers of the transformation of the sector (cf. Section 2.3). The expansion of access focused on equity, and universities were 'rewarded' according to a new funding formula (cf. Section 2.3). The increased participation rate of Black students (cf. Section 2.3), brought about issues of language (cf. Section 3.4) and under-preparedness for university due to a lack of teachers. In the present study less than 5% of Black students between the age of 20 to 24 years were successful. Proportionally more Black students were in the '*high-risk*' category, and language could be one of the major problems impeding academic progress (cf. Section 6.3.4). Although financial exclusions and personal constraints were identified as causes for student drop-out in the first year (cf. Section 2.3), the under-preparedness in specifically Mathematics (cf. Section 6.5) seemed to be the prevailing reason for a lack of academic achievement by first-year students (cf. Sections 3.4 and 3.5), as admitted by the Minister Pandor.
- Another policy directive, Enrolment Management, forced institutions to review admission processes and retention practices (cf. Section 2.4). Management of student throughput is of primary concern for institutions (Section 2.3 and 2.4). The integrated approach was emphasised as an academic measure to combat high failure rates. Widened access and increased throughput influence final subsidy (cf. Section 2.3), implying that students are admitted (only on school performance) but set up to fail.

- The importance of improving the actual quality of educational processes (cf. Section 2.5) impacted on institutions, specifically staff and students. Institutional quality audits via programme accreditations are monitored by the HEQC, and these processes created awareness in the sector with both lecturers and students striving for efficiency.
- The final two directives relevant to this study were increased subsidy for Science graduates and the fact that Sciences were identified as scarce skills (cf. Section 2.3). The Higher Education sector is encouraged to show greater reponsivity towards SA's societal and developmental needs. The shortage in graduates in Science, Engineering and Technology are stimulated with increased funding for these CESMs (cf. Table 2.2). However, the pool of students from which can be drawn, remained limited. Recruitment of potential students for programmes in SET remained in the domain of teacher enthusiasm, own school performance and quality of teaching, providing students with fundamental competence and skills to pursue further studies in SET (cf. Section 2.6).

*8.2.2.2 Higher Education Institutions*

In Figure 7.2, the Higher Education institutions are presented by a pentagon with a perforated edge, as universities should be able to absorb 'pressures' from the Higher Education sector. Below are some of the 'forced' reactions from universities resulting from the above policy drivers.

- Institutions display transparency in the transmission of knowledge, the dissemination of research, engagement with society and finally, the admission of potentially successful students within institutional enrolment and rolling plans (cf. Section 2.3). Management of enrolment and the subsequent review of admission processes are some of the additional institutional measures that should be pursued within every institution (cf. Section 2.4). Despite these efforts (and several others) increasingly mediocre to low throughput and academic achievement levels of first-year students, confirmed Higher Education Institutions' worst fears. Grade 12-results alone, were inadequate to indicate potential success at university level (cf. Section 6.4 and 6.5).
- Foundation and extended programmes were designed, and the "First-Year Experience" discussed at all levels of Higher Education (cf. Section 3.4). Institutions had to engage with one another, as all were experiencing similar challenges. Academic orientation is labelled as a meaningful strategy to 'weave' diversity into institutional culture, in an attempt to bridge the 'gap' between school and university (cf. Section 4.8).

- Universities widened access and enhanced student success of first-year students via strategies such as foundational support, extended curricula and alternative access programmes. The Limpopo University (UNIFY), University of Cape Town (AARP), University of Pretoria (UPFY) and University of Free State (University Preparation Programme) responded by assessing and supporting under-prepared students (cf. Section 2.3). The provision of earmarked funding in support of the aforementioned (cf. Section 2.3) assisted in the appointment of additional dedicated staff and necessitated adherence to policies and curricula.
- Management of throughput (cf. Section 2.4) should result in academic staff reflecting on teaching and learning strategies. The need to provide increased support to students with a ‘scaffolded’ approach to content is one of many options (cf. Sections 2.6, 3.4 and 4.6). Institutions that had practiced outcomes-based education for the past few years are of the opinion that the changed profile of incoming students causes them to lose credibility in the school system. HESA facilitated the development of the National Benchmark Test, the results of which are intended to inform universities about the level of competence and skills of entering first-year students (cf. Section 4.6). Lecturing staff were challenged and had no choice but to perform “constructive alignment” of the first-year curriculum to the school curriculum to ensure longer-term academic student success.
- Sectoral pressure to recruit more potentially successful students in Science programmes have not been addressed sufficiently and served as the main impetus for this study (cf. Section 2.6). Mathematics and Science at school level are not providing first-year students in Science-related programmes with the expected content knowledge and skills to be relatively successful in Higher Education (cf. Section 2.6 and 3.4). Despite seemingly (more than) adequate matriculation results, students enter the university and fail, increasingly perpetuating the revolving door syndrome (cf. Section 2.4). With debts to repay, unsuccessful students drop out and are obliged to start earning money, with the job market not exactly being accommodating in this respect. Potentially successful students (according to their Grade 12-results) have lost confidence in themselves and the institution (cf. Section 4.7). In essence, the Higher and further Education sectors have failed these students.

*8.2.2.3 The first-year student*

The majority of first-year students transfer from an inadequate schooling system to a foreign and challenging university system (cf. Section 2.6). In effect, the challenges these students are facing are almost insurmountable. Most students who enroll for Science-related programmes, enter with acceptable Grade 12-results, but many of them are under-prepared for university studies (cf. Sections 2.4, 2.6 and 3.4). The diverse South African schooling system is not providing learners with sufficient preparation in terms of Science-related content, the necessary academic exposure, study orientation or career counselling options. The Minister of Education has acknowledged that schools do not prepare students for further studies (cf. Section 2.6).

The university experience overwhelms new students. The thousands of other students, English as the language of teaching and learning (compared to home language at school), more work covered in the first quarter than during a whole year at school, and the differences between teachers and lecturers are all new experiences to adjust to (cf. Section 4.8). Students enter with some confidence and much expectation, having been in control at school, find a new freedom at university and should feel that they can manage on their own.

*8.2.2.4 The tension field in the Higher Education sector*

In Figure 8.1, the dynamics or rather mechanics within the sector is illustrated by using the analogy of forces pushing and pulling in different directions.

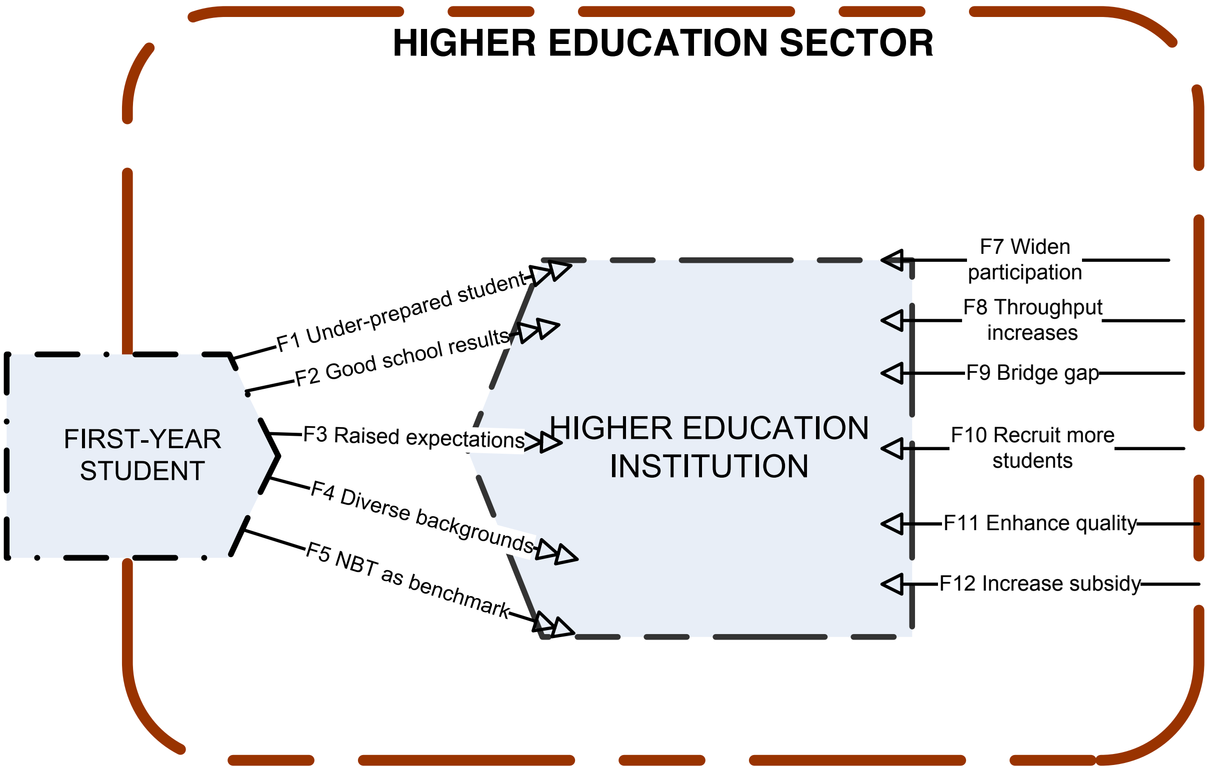


***Figure 8.1*** **Higher Education Institutions in a bipolar field of tension**

The challenges faced by entering Science students and the almost tangible tension between them and the university where they enrol, are captured as F1 to F6 in Figure 8.1. The figure indicates that institutions also experience tension, presented by different forces (F7 to F12) from Higher Education sectoral directives, constantly and increasingly impacting on them.

Examples of forces from entering students on the institution are: F1 (unprepared student [cf. Sections 2.6 and 3.4]), F2 (acceptable good school results [cf. Sections 2.6 and 3.4]), F3 (untapped potential [cf. Sections 3.3 and 4.2]), F4 (raised expectations [cf. Section 2.6]), F5 (diverse backgrounds [cf. Section 3.3]) and F6 (NBT as a benchmark [cf. Section 3.5]).

The examples of forces from the sector on the institution are: F7 (widened participation [cf. Section 2.3 and 2.5]), F8 (increased throughput [cf. Section 2.4]), F9 (bridging the gap [cf. Section 2.4]), F10 (recruiting more students [cf. Section 2.6]), F11 (enhancing quality [cf. Section 2.5]) and F12 (increased subsidy [cf. Section 2.3]).

There seems to be a clear disjuncture (indicated by the uncomfortable space) between the student and the university (and its programmes). This ‘space’ represents the real challenge of this study – an attempt to narrow the perceived distance between the student and the institution (specifically in Science-related programmes). In order to get the student 'shape' to align better and to attach to the institutional (programme) 'shape', the two entities will have to 'move' towards one another and adjust various aspects. The role of the institution and its Science programme-related practices and elements in "bridging the gap" and in reconciling apparent "disjunct shapes" (which in fact points to a process of duel reshaping), embodies the essential focus of this study.

The above state of affairs provides the necessary impetus for change within institutions. 'Forces' unleashed by the entering students (from the left) and by sectoral pressures (from the right), demands 'reshaping'. The proposed framework (cf. Section 7.3) present attempts to close the 'gap' in reshaping universities, with specific reference to Science programmes.

## 8.3 LIMITATIONS OF THIS STUDY AND RECOMMENDATIONS FOR FURTHER RESEARCH

During the course of this investigation limitations were identified and will subsequently be discussed. Although the sample included in this particular study was limited to one institution's degree programmes only, the outcome should be meaningful to stakeholders in the sector, not only to this particular institution. Nationally, students in Science programmes are failing and under-prepared students are entering all institutions. The lack of teachers and schools to provide well equipped students for Science programmes is an international trend, and the implications of this investigation should provide a scholarly contribution. An urgent intervention by universities to assist schools (teachers and learners) would possibly be a short-term solution.

Although the investigation was only performed in some degree programmes, the characteristics of Science programmes are general in nature and can be applied to various Science programmes. Degree and diploma programmes as well as programmes in Engineering, Health, Natural, Agricultural and other Science-related programmes all have generic Fundamental Sciences as part of their first-year curriculum. Outcomes of this study could therefore be adjusted to provide useful information to other programmes.

The sample did not include data collected from students in existing extended modules and programmes. Students from the Engineering and Science extended degree programme did participate but yielded small numbers and complicated data analysis. The structure of the extended programme changed during the past four years, and semester-modules were expanded to year-modules, creating problems with comparisons. Nevertheless, the results and proposals emanating from this study will be applicable to extended programmes with generic components similar to main stream options.

Data collection mainly took place during the two-week orientation period at the institution. Students who did not attend these sessions therefore did not form part of the sample. It could be argued that those who did not attend orientation would have influenced the outcome. Students who did not attend orientation were likely to be labelled at-risk students by the faculty, as they had already missed various opportunities, including meeting with lecturers, registering at the library and computer laboratory, and laboratory orientation. A compulsory orientation, such as some institutions have, would certainly assist with assessment, and academic orientation should be deemed important for academic success.

Changes in the school curriculum created one different Grade 12-group, namely the 2009-cohort. Students with National Senior Certificates were the first to write the 'new' Grade 12-examination which implied that results at school level and first-year level were difficult to benchmark. However, the fact that first-year performance was alarmingly poor impacted on institutions that were unprepared for this cohort. Follow-up tracking of the 2010 cohort will be valuable in order to compare the impact of the National Senior Certificate on first-year academic achievement.

The battery of measuring instruments used for student assessment was selected after research on available instruments, but within a limited budget. Many other instruments could be applied but it is doubtful if these would have rendered different results. The limited number of discreet admission attributes that were investigated can be expanded to provide a broader information base. A follow-up comparative study could verify results with other instruments and different circumstances, e.g. with the NBT-results that only became available recently. Although other institutions formed part of pilot studies, this sample did not have the opportunity to participate in the NBT. The NBT itself might also have limitations. The test was applied in degree programmes only. It needs to be developed further and tested with diploma programmes.

This study was not perfect, and more limitations than the abovementioned could possibly be identified. However, given the urgency and extent of the problem with Science programmes in SA, this study will contribute to awareness of problems in first-year Science modules. Lecturers and institutional managers will benefit from various aspects of the investigation. This could possibly result in reflection on policies and practices as well as a review of current procedures and even changed perceptions.

Further research will highlight the intensity of the institutional impact of unsuccessful students in Science programmes as well as on the gross economy of the country. The fact that the schooling system has systemic problems that will not be solved overnight shifts the burden to universities to find solutions. A follow-up comparative study at the same institution will be valuable, in order to investigate if any of the identified trends have changed. A longitudinal study will also provide an indication of predictors of success beyond the first semester of the first year. An increased number of students with National Senior Certificates would then have been allowed into the Higher Education sector.

As mentioned above, the investigation should be extended to also accommodate the indicators of success in Science diploma programmes and should certainly be added to the proposed framework. The articulation between degree and diploma fundamental Science content and skills needs to be investigated, and the correlation of the NBT and the Stellenbosch University Access Test should render further application. An increased number of guidelines (other than the four mentioned in Section 7.5) might be added as a result of further research.

It is recommended that this framework be verified by experts in the field of admission and Science education and be applied in other programmes and institutions. Nevertheless, the relevance of the findings, the recommendations and conclusions will contribute to the body of knowledge and stimulate further investigation.

## 8.4 CONCLUSION

The study intended to develop a framework for placement of first-year Science students and provided foundational principles that can be applied to other fields of study as well as by other institutions. The empirical research showed that additional variables to Grade 12-results had a statistically significant influence on student academic achievement. The literature review made a contribution towards the understanding and conceptualisation of predicting first-year academic success in Science modules. The study performed an overarching investigation across disciplinary boundaries and provided insights related to fundamental Science, e.g. Mathematics, Physics and Chemistry, that brought comparisons and variations unique to these fields, to the fore.

The researcher is convinced that the framework provides the Science educational field with an original contribution. Higher education and more specifically Science in Higher Education should take note that changes in practices (e.g. policy directives) and student profiles (widened participation, National Senior Certificate and the Outcomes-Based Education approach) will not change in the near future, implying that universities will have to change. The selection and buy-in from lecturing and support staff will have a pronounced effect on the effectiveness and efficiency of the application of the framework. Contemporary Higher Education is currently in a tension field (cf. Figure 8.1) and “reshaping” will have to take place. The framework will assist with transforming at least the “front door”.

The researcher has once again been reminded that quality teaching can change ordinary students into quality students and that the lecturer is the discipline. Enacting quality lecturing and being honest about attempting to turn every student into a Science scholar and ultimately into a scientist implies that lecturers, departmental culture and institutional ethos must change. By encouraging every lecturer and staff member to take ownership for student success the participants, places, policies, procedures and programmes might certainly be aligned to the purpose of the programme.

## 8.5 PRACTICAL IMPLICATIONS OF THE RESEARCH

The most prominent contribution of this study will be the conceptualisation of placement as part of admission practices and policies in Higher Education. The study was conducted at an institution and with a sample that reflected the South African population to the fullest.

Current admission policies for entering Higher Education based on Grade 12-results should include a comprehensive approach of collecting increased information about every applicant. Increased awareness of prior knowledge and scholastic proficiency will provide sufficient information on the academic profile of prospective students. The NBT-score should assist in this regard, with language ability assessment being absolutely essential. Additional information on the personality, interest, study orientation, as well as a background profile will provide sufficient data to be used to the benefit of student placement at an appropriate programme level. The framework will provide direction to guide admission and enrolment practices.

The second contribution of the findings is the proposal of instituting a structured extended qualification. The inclusion of holistic assessment of the student within the additional time to gain knowledge about him/her provides information to the institution. The real benefit for the student will be a slower beginning and linking to school content, making provision for adjustment. The addition of career counselling as an integrated module within the first phases will be of great value to the student. The framework was developed from an integrated approach across various curricula but with core components of fundamental Sciences. Thus, the framework acts as a wide lens across specific disciplines that impede progress in Sciences and introduces a solution towards academic success in Sciences.

The third implication resides within the core of academic departments. With specialised lecturers teaching the fundamental content, cultivating a learning environment and supporting students with study skills, time and human resources should be allocated wisely. Increased throughput will ensure that more students graduate and higher subsidy be granted to institutions. An increased number of students feeding into post-graduate programmes will indirectly stimulate research and directly allow lecturers to teach content and not spend additional time on academic support and literacies. The research therefore contributes to an integrated management system of Science in Higher Education.

Finally, this investigation probed Science programmes in Higher Education. Although universities have been in the "knowledge business" for centuries, Science disciplines need to take note of what is required to change and become flexible, in order to adjust to the changing student profile and learning environment. Curriculum and teaching must adjust to the level of entering students and yet still maintain the provision of graduates with the required competencies and skills. The framework will contribute towards widening the basis for continued research on admission, enrolment management, teaching and learning in Science, while aiming to assist students to become graduates and guide universities to provide successful students. The most challenging endeavour possibly lies in convincing Science specialists that change and transformation might be the only way to survive in the 21$^{st}$ century.

## 8.6 CONCLUDING REMARKS

There is no simple and obvious solution to alleviate poor first-year student academic achievement in Science programmes. With the current South African school curriculum and lack of qualified teachers to teach Mathematics and Science, universities are obliged to change their own destiny. This study contributed to the understanding of the predictive value of post-admission attributes in Science programmes. It indicated that to predict the academic achievement of any student is a complex problem that can only be resolved if given time and resources to place students where they "fit" best. The investigation into indicators of success provided a urgency that institutions develop the ability to identify at-risk students as soon as possible and create alternative programmes to provide students with integrated and contextualised academic and social support.

The study was conducted at a Higher Education institution with a student body that resembles a true reflection and representation of the South African population. The results should thus be generalisable to the broader Higher Education environment in South Africa. Other contributions made by this study include the integration of research across the boundaries of disciplines (e.g. Mathematics, Chemistry and Physics) and use of statistical techniques rarely used to analyse data.

It is hoped that the contribution made by this study to the ongoing quest to find solutions for increased throughput and the debates on admission of the "right" students, will assist in making progress towards enhancing academic achievement in the South African Higher Education context.

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