STUDYING SCIENCE AND ENGINEERING AT UCT: STUDENTS' BACKGROUND, EXPERIENCE OF SCIENCE AND REASONS FOR STUDYING SCIENCE OR ENGINEERING

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: …………………………………

Date: ………………………………..…..

ABSTRACT

It is the contention of this study that competence in science and mathematics is a necessary condition for access to higher education, but that it is a general interest in science that will inspire learners to pursue careers in science and technology. The objective of this study was to develop a profile of the individual who chooses to study science and engineering. The three research questions were, firstly, what is the background profile of a group of learners who have decided to study science and engineering? Secondly, what are the characteristic features of the school-science experience of these learners? Lastly, what are the factors that learners think most influenced their decision to study science and engineering?

This study was formulated as having a descriptive purpose and hence a survey research design was used. Self-reported retrospective data were collected using a questionnaire which was designed with reference to a number of sources (e.g., Woolnough, 1994). After piloting the questionnaire, it was administered to all first-year students registered in the faculties of Science and Engineering at the University of Cape Town. A total of 204 first-year science and 247 first-year engineering students formed the final sample of this study.

Quantitative analysis of the students' responses showed that 66% of respondents were male. The majority of female students were registered in the science faculty. English was the home language of 55% of the sample, with 32% of students reported speaking one of the other nine official languages at home. Parents, career counselors and teachers most influenced students' decision to study science or engineering. The vast majority of respondents took Physical Science at school. Students' experiences of school science were diverse. Students' responses generally reflected a poor commitment on the part of schools to expose students to non-curriculum activities generally thought to promote an interest in science. Overall, the majority of students reflected an enthusiasm for learning to do science through scientific experiments, albeit with preference for a teacher-driven approach to classroom activities. Personal motivation, receiving a bursary, and access to information were the main factors that students said influenced their decision to study science and engineering. While information received at a careers open day and participating in a school science competition was crucial for science students, engineering students showed a general curiosity for science, for knowing how things work, and for creating and designing things. For most African students information received at a careers open day was important, while a curiosity for science and receiving a bursary were equally important in influencing non-African students to pursue further study in science or engineering.

The results of this study suggest that what parents say, and the information that learners have access to, is important to the decisions that learners make in regard to future careers in science and engineering. It is suggested that future strategies for promoting science in general must include parents, teachers and senior learners in the dissemination of general information about science, about people in science, about using science in everyday life, and about the possibilities for further study in science and engineering.

OPSOMMING

Dit is die uitgangspunt van hierdie ondersoek dat vaardigheid in die wetenskap en wiskunde ‘n noodsaaklike voorwaarde is vir toegang to tersiêre onderwys, maar dat ‘n algemene belangstelling in die wetenskap leerders sal inspireer om loopbane in die natuurwetenskappe en tegnologie te volg. Die doel van hierdie ondersoek was om ‘n profiel te ontwikkel van die individu wat die natuurwetenskappe en ingenieurswese kies as studierigting. Die drie navorsingsvrae was, eerstens, wat is die agtergrondsprofiel van leerders wat besluit om in die natuurwetenskappe en ingenieurswese te studeer? Tweedens, wat is die kenmerkende eienskappe van hierdie leerders se skoolervaring? Laastens, watter faktore dink hierdie leerders het hulle besluit om in die natuurwetenskappe en ingenieurswese te studeer, die meeste beïnvloed?

Hierdie ondersoek is beskrywend van aard en dus is ‘n steekproef as navorsingsontwerp gebruik. Selfgerapporteerde retrospektiewe data is ingesamel deur middel van ‘n vraelys wat ontwerp is met verwysings na ‘n verskeidenheid bronne (bv., Woolnough, 1994). Die vraelys is versprei aan alle eerste-jaar geregistreerde studente in die Natuurwetenskappe en Ingenieurswese Fakulteite by die Universiteit van Kaapstad, nadat ‘n voortoetsing van die vraelys uitgevoer is. ‘n Totaal van 204 eerste-jaar natuurwetensakppe en 247 eerste-jaar ingenieurswese studente was deel van die finale steekproef van hierdie ondersoek.

Die kwantitatiewe ontleding van die studenteterugvoer toon dat 66% van die respondente manlik is. Die meerderheid vroulike studente was geregistreer in die natuurwetenskappe fakulteit. Engels was die huistaal van 55% van die steekproef, en 32% van die studente het aangedui dat hulle een of meer van die ander nege amptelike landstale praat. Ouers, beroepsvoorligters en onderwysers het die meeste invloed gehad op die studente se besluit om in die natuurwetenskappe of ingenieurswese te studeer. Die oorgrote meerderheid respondente het Natuur- en Skeikunde op skool geneem. Studente se skoolervarings en ervaring van die wetenskap op skool was uiteenlopend. Studente se terugvoer het in die algemeen gedui op ‘n swak verbintenis van skole tot die blootstelling van studente aan nie-kurrikulêre aktiwiteite wat oor die algemeen belangstelling in die wetenskap kweek. Die meerderheid studente het in die geheel ‘n entoesiasme getoon om meer te leer

van die wetenskap deur die uitvoer van wetenskaplike eksperimente, hoewel met ‘n voorkeur vir ‘n onderwyser-gedrewe benadering tot klaskamer aktiwiteite. Persoonlike motivering, om ‘n beurs te ontvang, en toegang tot inligting is deur studente aangedui as van die vernaamste faktore wat ‘n invloed op hulle keuse van die natuurwetenskappe en ingenieurswese as studierigting gehad het. Die inligting wat die natuurwetenskappe studente ontvang het by beroepsgeoriënteerde opedae en deelname in ‘n skool wetenskapskompetisie was beslissend in hulle besluit. Die ingenieurswese studente daarteenoor het ‘n algemene nuurskierigheid vir die wetenskap en hoe dinge werk, hoe om dinge te skep en te ontwerp, getoon. Die inligting wat swart studente by beroepsgeoriënteerde opedae ontvang het, was belangrik, terwyl ‘n wetenskaplike nuuskierigheid en die toekenning van ‘n beurs ‘n ewe belangrike invloed gehad het op ander studente se keuse om verdere studie in die natuurwetenskappe of ingenieurswese voort te sit.

Die resultate van hierdie ondersoek dui daarop dat wat ouers sê, en die inligting waartoe leerders toegang het, belangrik is vir die besluite wat leerders neem met betrekking tot toekomstige loopbane in die natuurwetenskappe en ingenieurswese. Daar word voorgestel dat toekomstige strategieë vir die bevordering van die wetenskap in die algemeen ouers, onderwysers en senior leerders moet insluit in die verspreiding van algemene inligting oor die wetenskap, oor mense in die wetenskap, oor die gebruik van die wetenskap in die alledaagse lewe, en die moontlikhede van verdere studies in die natuurwetenskappe en ingenieurswese.

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Finally, I dedicate this piece of work to my daughter Kristina, whose arrival sent me down a bumpy road because it exposed all my inadequacies; and to my son Alexander who later showed me that these do not matter.

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PERSONAL PREFACE

I am aware that there is a time lag between the data collection and write-up phases of this study, and this issue is addressed here. This study asks students to reflect on factors that may have influenced their decision to pursue further studies in science and engineering after completing school. Many of these factors relate to influences within their personal environments and the validity of these factors in influencing the decisions that students made had not changed. With respect to how students experienced science the effect of several non-curriculum related activities were investigated which are unlikely to have been affected by policy and curriculum changes implemented in schools in the past few years. It is thus thought that the data remains valid and that the results reflect the limited way in which a general interest in science is still being promoted in schools today. I believe that the findings of this study provide a useful representation of the in- and out-of-school factors that influenced students to enter higher education after school. Useful insights into resources that schools may access and utilize to promote a climate positive towards science are offered.

Chapter One

GENERAL INTRODUCTION

Background and rationale

One of the most notable features of the modern epoch is the extent to which life in many Western societies has changed as a result of advances in scientific and technological innovation.

> It is the coded band on supermarket items; it's the nylon blend in shirts; it's the aerodynamics of the Frisbee. Cinematic special effects, bioengineered tomatoes. (When I was in school, science …, 1988:14)

Then again, one may also talk about change with respect to significant improvements in our material well-being, as symbolized by the motor car, microwave ovens, cellular telephones and electronic communication. Significant breakthroughs in healthcare have also been noted such as, for example, the eradication of certain diseases, vaccines and laser beam surgery. Similarly, automotive engineering, microelectronics and information processing have had an enormous impact on the way that goods are manufactured. We could also describe change in terms of the risks that it presents. Here, we may focus on how scientific and technological research is applied, such as, for example, the dangers of nuclear power or the ethics of genetic engineering.

Examples such as these are certainly one useful way of describing social change. One could argue that they provide an indication (or documentation) of the extent to which society as a whole has benefited from scientific and technological development. Or, they could be used to demonstrate that the extent to which the benefits of scientific and technological development have permeated peoples' lives is universally not the same—citizens in the developing world are likely to describe change very differently to those in developed countries.

In recent years, an increasingly sophisticated international literature has broadened our understanding of how the social and economic world is being transformed. It is widely argued that Western societies are experiencing a major change, heralding a new era which has been variously described as post-industrial, in terms of the rise of the information society or knowledge economy by analysts concerned with the economic character of change, or as post-capitalist or post-modern by those concerned with the political character of change (Wilson & Woock, 1995). Brown and Lauder (1991) summarize as follows: "This transformation was signaled by the first 'oil shock' in the early 1970s and has been the result of a number of factors including the technological revolution in communications, computers and robotics; globalisation; and the rising competitive force of Pacific Rim countries" (1991:3). Furthermore, at the epicenter of this transformation is the creation of a global economy, the key elements of which are described as follows:

> The globalization of markets for goods and services … technological innovation and cheaper transportation costs has led to an intensification of economic competition between firms, regions and nation states. Advances in information technology have contributed to increased levels of productivity and to the development of flexible forms of accumulation offering the opportunity of high-value, low-volume manufacturing in place of mass production of standardized products. (Brown & Lauder, 1995:19)

However, when we speak about the nature of change, it is also often argued that we need to consider the implications that current developments in science and technology have had on other aspects of life. For example, Freund (1992) examines the implications that technological innovation has for the labour process, with respect to changes in our consumer habits and the *way* that goods are produced. Hurd (1989), Giordan (1995), and Longbottom and Butler (1999) point out that our concept of work is changing. Consequently, we have new uses of leisure time. "Under capitalism, production has been stimulated to the point where it is feasible to eliminate the daily struggle to meet the necessities of life; this productivity holds out the tantalizing possibility of all humans being freed to seriously consider the quality of life" (Longbottom & Butler, 1999:479). For others (e.g., Hodson & Reid, 1988; Host, 1995; Kahn, 1995) the quality and competency of human capital is considered important. Increasingly, it is being demonstrated that through advances in the technologies of communication, data processing, food production, transportation and manufacturing, scientific and technological processes are able to offer society new ways of doing things, new possibilities for social upliftment, and a new basis through which countries communicate and trade. Hence, it is argued that "knowledge, learning, information and technical competence" (Brown & Lauder, 1995:21) have become important for economic prosperity and social progress. This in turn, presupposes that we promote conditions that make it possible for individuals to interact with science and technology in their everyday lives.

Underlying much of the current international literature is what is commonly referred to as the Science-Technology-Society (STS) movement—developed in response to students' inability to use science in their everyday lives (Fourez, 1995). Fourez (1995) very broadly distinguishes between two, not necessarily mutually exclusive, currents of the STS movement. The first, often used by developing countries, argues that given limited resources, science and technology should "place itself at the service of progress" (1995:29), relevant to everyday life and be aimed at guiding humanity to a better future. The second current, widespread in the industrialized world, makes use of a literacy metaphor. It argues that just as the ability to read and write is widely valued, "a certain kind of knowledge" (Fourez, 1995:29) has become necessary in a world where science and technology have already extensively permeated the social and economic lives of individuals. Fourez (1995) suggests that the emergence of this current may be attributed to the need to manage major technologies with respect to issues such as pollution, accidents, exploitation, deprivation, and so forth. Consequently, human action becomes important, but this relies on a strong democratic culture, one in which a humanized, critical, scientifically and technologically literate citizenry is valued, is able to make informed and responsible decisions, and is encouraged to act upon these decisions (Fourez, 1995; Pedretti, 1997). It is within this global context, that countries worldwide have been developing and/or reshaping their national strategies for scientific and technological (S&T) literacy, development and research.

In South Africa, the *White Paper for Science and Technology* (Department of Arts, Culture, Science and Technology [DACST], 1996) established (for the first time) a policy framework for the future role of science and technology in the country. A basic feature of the White Paper is that it subscribes to the global view that science, technology and innovation are central to future strategies for economic development, economic vitality and social progress. It is based on a view for the future "where all South Africans will enjoy an improved and sustainable quality of life, participate in a competitive economy by means of satisfying employment; and share in a democratic culture" (DACST, 1996:3)—which is consistent with Fourez's (1995) view on how S&T is seen in developing countries. Furthermore,

> The core vision of the White Paper is the conceptualization of a national system of innovation which seeks to harness the diverse aspects of S&T through the various institutions where they are developed, practiced and utilized. No government can order innovation to take place, but government can ensure that a competent pool of expertise from which innovation can spring is grown and maintained. This is where the White

> Paper strongly addresses the need to invest in people at all skill levels. The policy thrusts of this White paper are in harmony with the White Paper on Education and Training in its identification of investment in mathematics, science and technology as a fundamental goal. (DACST, 1996:3)

Support for a National System of Innovation (NSI) is widely acknowledged as commitment from government to re-prioritise historical funding scenarios. A decade ago, Science and Technology (S&T) research in South Africa was criticized for reflecting a view of South Africa more as part of the industrial world rather than a developing country (Independent Development Research Centre (IDRC), 1992; Cleary, 1995). The African National Congress (ANC) then asserted that historically the agenda for S&T research in South Africa was set by "military requirements … to serve the needs of state security … rather than economic efficiency and social equity" (IDRC, 1992:1-2). The NSI, therefore, has been modeled as "a set of functioning institutions, organizations and policies that interact constructively in the pursuit of a common set of social and economic goals and objectives, and that use the introduction of innovations as a key promoter for change" (Department of Science and Technology (DST), 2002:19). The main institutions that comprise the NSI are the nine science research councils, government research institutes and museums, as well as the research universities (Cape Town, KwaZulu-Natal, Pretoria, Rhodes, Stellenbosch and Witwatersrand).

Within this context, the distinction that is generally made between innovation and research and development (R&D) becomes relevant. The NSI framework defines innovation "as the introduction into a market (economic or social) of new or improved products and services" (DST, 2002:19). Research and development on the other hand, is "the conscious and systematic scientific effort that contributes to the growth of the stock of knowledge that in time may or may not lead to new technological applications" (Kahn & Blankley, 2006:271). In the process of innovation, therefore, R&D may or may not have been an important component. Nevertheless, Kahn and Blankley (2006) point out that a great deal of technological innovation involves R&D. This being the case, they assert that R&D capacity is important for sustainable innovation—"without investment in basic research the flow of new thinking may be stultified, and the flow of innovation activity may wither" (Kahn & Blankley, 1996:270-271). It is the development of <u>such</u> R&D capacity that is widely understood to be tied to the quality of the mathematics, science and technology education of citizens.

The importance of mathematics and science knowledge and competence for development has been central to much of the education policy and curriculum reform introduced in South Africa in the last decade (DST, 2002). In 1995, the Department of Education (DoE) introduced an experimental school redress programme–SYSTEM—which offered a second chance to learners who had under-performed in the Senior Certificate Mathematics and Physical Science examinations. "SYSTEM sought to increase the flow of quality black matriculants both to university science-based careers and toward teaching careers" (Kahn, 2006:129). This programme was terminated in 1999. In 1997, Curriculum 2005 with its outcomes-based philosophy was introduced and revised in 2002. In the previous curriculum all learners took general science and mathematics through Grades 1 to 9. In Grade 10 learners could choose to study Mathematics, Biology or Physical Science. Curriculum 2005 and the revisions made to it subsequently changed this. From 2006 onwards, all learners registered in Grades 10 to 12, the FET (high knowledge and high skill) phase, must study mathematics—either in the form of mathematical literacy or mathematics. In 2001, a national strategy to improve science, mathematics and technology education in South Africa was announced (DoE, 2001), and in 2004 a second phase was approved (DoE, 2004). This second stage will be implemented in 2005-2009. In this strategy—more commonly known as the *Dinaledi* project—102 schools were initially identified countrywide that had the potential to perform well in science and mathematics. The primary objective of this initiative is to provide each province with resources to promote and support effective science and mathematics teaching and learning, but to concentrate these 'scarce' resources at a small number of designated sites in each province. While Reddy (2006a) points out that it is premature to comment on whether the anticipated gains in performance and participation have been achieved, Kahn (2006) acknowledges the *Dinaledi* intervention as an effort "made to ameliorate conditions for teaching and learning, an effort that included investment in technology enhanced learning and in-service education and training" (2006:130).

Statement of the problem

The policy reform initiatives that we have seen in the past decade, aim to improve the overall provision and quality of science and mathematics education to <u>all</u> learners in South African schools. However, if we use the performance indicators used in the Trends in International Mathematics and Science Studies (TIMSS) (Howie & Hughes, 1998; Reddy, 2006b) then, by international standards, South Africa is performing poorly in science and mathematics—in TIMSS 2003 which tested the mathematics and science proficiency of Grade 8 learners, South Africa came last of the 50 countries who participated (Reddy, 2006a). It is understood that the underlying thinking behind these initiatives is that by improving learner competence in science and mathematics, South Africa will significantly increase the number of learners who are eligible for access to science-based study at higher education institutions—necessary if we are to grow our pool of technical expertise. However, it is the contention of this study that being eligible to enter a higher education institution is no guarantee that a learner will actually wish to do so. Competence in science and mathematics is a necessary condition for access to higher education, but students are not inspired to pursue science-based careers only because they are good in these subjects. Instead, I argue, that it is a general interest in science that will inspire learners to be scientifically and technologically innovative as adults; to debate on how science and technology should be applied in addressing developmental issues (e.g., in the provision of water, water purification, sanitation, transport, the use of alternative energy, communications, etc.); to be concerned with the pressures that development may place on the environment (e.g., soil erosion, water conservation); to be able to make sound decisions in their personal lives with respect to science-related matters (e.g., nutrition, health) and **for some**, to pursue scientific or technological study at the post-school level, and later a career related to science and technology. The challenge, therefore, is in developing strategies that will, alongside the formal curriculum, nurture an interest in, and enthusiasm for, science amongst learners.

Aims and objectives of the study

It is argued here that several factors motivate learners to take an interest in science, to appreciate science, to enjoy science, and, for some, to pursue careers in science and technology. For example, in their study of the factors that affect learners in England, Australia, Canada, China, Portugal and Japan positively towards science and scientific careers, Woolnough et al. (1997) showed that the school environment (which includes the formal curriculum), the role that parents play, the attitudes that learners have about science in general, and the input and involvement of other interest groups, such as scientists visiting the school, were important. It is the aim of this study to examine the role that some of these factors have played in encouraging a group of South African learners to study science or engineering after completing school. The learners who participated in this study had actually made the decision to pursue a career in science or engineering and at the time of data collection, and were registered as first—year students at the University of Cape Town (UCT).

The objective of this study is to develop a picture of what the individuals who choose to study science and engineering look like with respect to their background influences, the type of facilities that were available to them at school and the type of science-related activities that they encountered at school. Learners' self-reported perceptions of the effect that these, as well as specific out-of-school science experiences, have had on their decision to study science and engineering will be examined.

Significance of the study

It is argued that if one of the objectives of educational change is to encourage learners to pursue careers in science, engineering and technology, then we must be aware that the number of learners who will actually do so, depend on more than just those who meet the academic requirements for admission into higher education institutions. We need to consider that the decisions that students make are influenced by a variety of factors, some of which may be utilized and manipulated within the school environment. It is argued that the information sought in this study could inform a strategy to use multiple influences to popularize science in schools and in this way, promote a climate positive towards science and careers in science.

Assumptions

It was assumed that the fact that students decide to pursue further study after school, says something about their career aspirations. It was therefore considered reasonable to assume that students who have chosen to study science and engineering at university will one day have a career in a science or engineering related field. Throughout this thesis no distinction is made between studying science and engineering and career choice.

Research questions

The central assumption upon which this study is based, is that the factors that encouraged learners to pursue a career related to science and technology are related to their background, the science experience/s that they had in school, to the science experience/s that they had out of school, their attitudes towards science and to their perception of the value of a scientific and technological careers. Hence, this study will attempt to answer the following questions:

1. What does the background profile of a group of learners who have decided to study science or engineering look like?
2. What are the characteristic features of the school-science experience of these learners with particular reference to school facilities, non-curriculum science-related activities and the nature of science classroom activities?
3. What are the factors that learners think most influenced their decision to study science and engineering?

Where appropriate, comparisons between subgroups of learners—defined by race, gender and faculty of registration—will be investigated.

Clarification of terms

In this study, *learner* refers to an individual who is enrolled in the school system. The term m*atric* is used as an abbreviation for matriculation and refers to the school leaving examination written at the end of the final year of school (Grade 12) in the South African schooling system. *Matriculant* refers to any person who has successfully completed the Grade 12 senior certificate examination. Throughout the thesis the terms science and technology and science, engineering and technology are used synonymously.

Outline of thesis

In the following chapter, it is argued that South Africa's participation in a globalizing world has implications for its social, economic and educational development, as well as for the entrenchment of a democratic culture in which citizens must be able to contribute to decisions on how innovation may be used to change their lives. In Chapter 3, studies on how learners interact with science are examined, and I present an overview of the factors thought to encourage learners to pursue further study, or a career, in science. The methods and procedures used to investigate factors which have encouraged a group of learners to register for science or engineering at UCT is presented in Chapter 4. Chapter 5 describes the results of the study. These results are based on an analysis of students' responses to questions about their personal background, their school background and their in-and-out-of-school experiences of science and the factors that they believe influenced their decision to study science and engineering. In the final chapter, the results are discussed and recommendations for possible strategies to promote a culture positive towards science amongst school learners are offered.

Chapter Two

THE CONTEXT OF THIS RESEARCH—WHY IS SCIENCE AND TECHNOLOGY EDUCATION IMPORTANT?

Introduction

In the previous chapter, a brief overview of the science education policy reforms that have been implemented in South Africa in the past decade was presented. It was argued that increasing the number of learners who go on to higher education must be seen as one of the objectives of these reforms, but that a pre-requisite for this was that learners' interest in science must be developed and nurtured. In this chapter, I provide reasons for why I believe developing and nurturing such an interest in science amongst South Africa's citizens is desirable. The first reason relates to issues of empowerment. Here, it is argued that South Africans need to examine how they exercise their democratic right to contribute to decisions on how science and technology is used to bring about social change. The second reason relates to the implications that new technologies have for the South African labour market. It is argued that these are likely to have implications for future work organization, and how workers negotiate these changes will become increasingly important. Lastly, the implications that the changing scientific and technological environments have for the provision of education, particularly science education, are discussed.

Democratic reason

In the previous chapter, reference was made to the distinction that Fourez (1995) draws between two currents in the STS movement. Fourez (1995) points out that in developing countries science is largely expected to guide humanity to a better future. At the same time, however, he argues that in a science- and technology-orientated society, some degree of scientific and technological knowledge favours the autonomy of the individual in that it enables him/her to negotiate reasonable, rational and informed decisions about their needs and interests in their adult lives (Fourez, 1995). Indeed, we could argue, the ability to make such decisions speaks directly to the democratic rights of citizens to access information, to ask basic questions, and to contribute to decision-making on scientific matters that might impact on their lives.

But how do South Africans really value their democratic rights? If we define democracy in terms of an improved quality of life, equal opportunity, and freedom from oppression and the power to determine who would govern, then all that is required of citizens is to sit back while government does its job—hopefully offering all of the above. What, though, about the role and responsibility of ordinary citizens to contribute to the democratic processes in society? One could argue that South Africans have never been educated for a model of democracy "in which all citizens express their humanity by making rational choices about their own lives, and where each of them is able to join others in influencing the general direction of society" (Longbottom & Butler, 1999:476). One reason for this may be that apartheid ideology placed little emphasis on individual choice and the right of individuals to engage with political processes. Furthermore, and this applies also to the period since achieving democracy, South Africans are unlikely to ponder any enlightened meanings of democracy in the face of socially destructive conditions.

Longbottom and Butler (1999) rightly argue that any movement toward a truly democratic system "is retarded by the economic impotence of many and the general ignorance of most when it comes to understanding the processes and power structures in society. The rationality of a person's decisions is in question if they fear when the next gang shooting will take place; if they fear what they will be forced to do in order to feed their family; or if they exist without thinking, without a vision and without hope for the future" (1999:467). Are we to assume, therefore, that until such time that parity with respect to the availability of basic services has been achieved, South Africans will aspire to democratic ideals that are motivated by their own interests and the need to improve the quality of their lives?

Longbottom and Butler point out that there are indeed models of democracy that have developed within capitalism that are based on "the primacy of the individual" (1999:476). Responsibility for governance is passed on to politicians (i.e., the professionals) while citizens are free to pursue their own material needs, interests, wants, and leisure activities. The problem with this approach, however, is that it places little emphasis on collective sharing of national goals (and so is not truly democratic), and it compromises the autonomy of ordinary citizens to actively participate in the processes that promote national goals (Longbottom & Butler, 1999:476). In my view, there are two reasons why these shortcomings are of particular relevance for present-day South Africa. Firstly, if we expect citizens to buy into government's vision of a society where "all South Africans will enjoy an improved and sustainable quality of life; participate in a competitive economy by means of satisfying employment; and share in democratic culture" (DACST, 1996:3), then a model based on the primacy of the individual may not be desirable. Secondly, if South African citizens are indeed to be encouraged to participate in the processes that promote national goals, then this implies is that they need to be educated for democracy. With respect to developments in the scientific and technological environment, this would mean encouraging citizens to

a) think about the contribution that science and technology has made in society;
b) become conscious of how scientific and technological innovation has affected their lives, and thereby determine the role that they wish it to play in bringing about change to their lives in the future;
c) be realistic about their expectations, given available economic and human resources; and
d) understand the ways in which they are able to influence the values, practices and ethos that will determine how science and technology is used in bringing about social change.

Fourez (1995) suggests that when citizens take an interest in the processes that promote national goals, and when they are sufficiently empowered to make rational and informed decisions about their needs, we have a criterion for judging the importance of knowledge. It allows us to distinguish between knowledge that increases our dependence on experts and knowledge that enables us and experts to establish a more egalitarian partnership. It is my view that this is a particularly relevant distinction for South Africa, particularly at a time when we are addressing our **own** ability to utilize developments in science and technology to bring about social change and to achieve national goals. In my view, the education policy reform initiatives outlined in the previous chapter suggest a commitment, at policy level, to promoting the notion of knowledge and learning as important for personal as well as social progress.

Economic reason

The second reason why it is considered desirable to develop and nurture an interest in science amongst citizens, relates to the philosophy that will shape South Africa's economic development within the new global economic context. It is not unreasonable to assume that in the future the number of international economic partnerships that South Africa will enter into will increase. At one level, such partnerships increase South Africa's exposure to the rules and obligations that govern how nations interact in a global environment. At the same time, however, we need to recognize that they will also draw South Africa into the web of changes taking place at a global level with respect to the creation of a global economic order.

In recent years, much of the discussion around global economic development has been conceptualized in terms of a shift from one particular mode-of-production paradigm (i.e., Fordism)[1] to another. Hence the emergence of terms such as the post-industrial, post-modern or post-Fordist paradigm. It is often suggested that how this transition has been conceptualized has been influenced by the regulation theorists who "hypothesize particular regimes of accumulation under which capitalism advances historically" (Freund, 1992:2). Regulation theorists argue that capitalism relies on a particular kind of relationship between social and financial arrangements. Furthermore, over time, and often through state intervention, these social and financial arrangements are institutionalized, thereby producing a particular regime. This system of reproduction may be viewed as a 'mode of regulation' (Kraak, 1992). It is often suggested that Fordism may be understood as one such mode (Kraak, 1992). Consequently, the defining features of Fordism are often discussed by scholars in ways that attempt to draw analogies with regulation theory principles.

For example, Brown argues that "Fordism is a label that can equally be applied to Keynesian demand management in the postwar period referring to the expansion of mass consumption as well as mass production" (1996:3). *At the level of mass production*, 'economies of scale' and maximizing machine utilization were the catchwords of the system. Brown (1996) explains this by outlining that Fordism was initially characterized by the manufacture of large numbers of identical cars. Key to Fordist mass production, however, was that it was primarily based on the production of standardized products. Crucial to this process was the mechanization of many of the tasks previously done by skilled artisans "by designing jigs, presses and machines able to perform the same operations hundreds … of times a day, with the use of a semi-skilled operative" (Brown, 1996:3). A second feature of Fordist mass production was that it associated an increase in productivity with the breaking down of the labour process into fragmented tasks (Brown, 1996; Harvey, 1990). Again, mechanization facilitated this process by enabling moving assembly line production whereby "the product passes the workers along a conveyor, rather than the worker

[1] The term 'Fordism' is generally used to refer to the industrial system under which manufacture took place in the first half of the twentieth century. It is symbolized by the 'Model T automobile' designed by Henry Ford in 1914.

having to move to the product as in nodal production" (Brown, 1996:3), thereby essentially restricting a worker's task to one aspect of production only. Consequently, Fordist mass production is often linked to F.W. Taylor's principles of scientific management which offered a justification for "the separation of conception from execution, where managers monopolized knowledge of the labour process, and controlled every step of production (Brown, 1996:4). *At the level of mass consumption*, Ford's introduction of the five-dollar-eight-hour-day represented a compromise between employers and organized labour (Brown, 1996:3). Freund argues that "it represented a trade-off whereby most workers lost autonomy but made economic gains" (1992:4). However, he identifies two spin-offs of the social security that economic gains provided. Firstly, workers were encouraged to consume the ever-increasing range of mass produced products. In turn, this stimulated the extension of mass consumption in society at large (Freund, 1992:4; Harvey, 1990:126). The depression of the 1930s is at times cited as the point where state intervention became firmly connected with Fordism (Harvey, 1990; Kraak, 1992). Also referred to as *Keynesian state intervention*, fiscal and monetary policies of many western capitalist states, after the depression of the 1930s, provided an infrastructure aimed at ensuring sustained economic growth by regulating profits and wage levels (Harvey, 1990:127). "Hence the development of the welfare state in western industrial societies was seen to reflect efforts on the part of national governments to maintain the Fordist compromise between employers and organized labour" (Brown, 1996:3).

Advances in computer technology in the last two decades are widely argued to represent a shift away from automation confined to <u>local</u> networks, as was the case with Fordist production techniques. Often referred to as the third industrial revolution or post-Fordist era, it is often argued that on-going improvements in computer and communications technologies have far reaching implications for the rules that apply to wealth creation and economic prosperity. For example, Freund argues that

> computers make possible a post-Fordist manufacturing world whereby processes can connect different production events at different factories with great efficiency, thus creating unprecedented flexibility. … In order to maximize manufacturing going together with ideal conditions of wage and labour control, every part is made in at least two different plants (and usually, countries). … since the mid-1960s, the internationalization of electronic manufacturing has led to the emergence of pervasive global sourcing networks linking the most diverse production activities and complementary services, irrespective of their geographic location. (Freund, 1992:3)

Often referred to as Computer Integrated Manufacture, the post-Fordist paradigm is therefore generally used to explain a) the shift away from the production of standardized goods to customized production, and b) the emergence of a world-economy dominated by services (e.g., finance, trade, real estate, transportation, etc.) (Freund, 1992).

However, it is also often argued that the introduction of post-Fordist technologies represents a major change to the Fordist employee-employer-government relationship described earlier. *For management*, the shift from automation to computerization has meant tremendous control of production. New computer technologies do not separate data programming and data processing, thereby making it possible for production sequences at different plants to be programmed to perform different tasks at different times. It is this flexibility linking design and planning decisions to manufacturing processes (particularly across plants) that makes it possible to concentrate on the production of a variety of products, often in smaller runs of production for differentiated (potentially profitable) 'niche markets' (Freund, 1992:3). *For labour*, it is widely accepted that the computerization of production processes is likely to require important new kinds of skill. It is argued that post-Fordist production techniques will increasingly rely on a labour force which is numerate, has a basic level of skill in elementary statistics and has some understanding of the principles of science and technology applied in production processes. Furthermore, the shift to flexible manufacturing and product variety will increasingly require a labour force that can be flexibly used to improve the quality and efficiency of the production process. As a result, problem diagnosis skills, decision making skills, the ability to do more tasks along the line, the ability to integrate different levels of conception, and the ability to co-ordinate and co-operate with other manufacturing units are widely expected to become important characteristics of a 'flexible' labour force (Freund, 1992; Lewin, 1995; Mathews, 1989).

In short, it is widely argued that the future labour force will a) play a crucial role in supporting and improving innovative production techniques, and thereby b) play a crucial role in how effectively countries will participate in the new global economic order. The impact that the emergence of a world economy has had on labour with respect to skills formation, work organization and industrial relations is one example of how the role of *government* is likely to change in a post-Fordist economy. It is expected that trade unions will largely be responsible for negotiating changes to work organization, and that these changes will have implications for future job classifications and skill requirements. Brown argues, therefore, that rather than maintaining the Fordist employer-trade union compromise,

> the state must prevent the unions from using their 'monopoly' powers to bid-up wages which are not necessarily reflected in productivity gains. Hence, according to the market rules of engagement, the prosperity of workers will depend on an ability to trade their skills, knowledge and entrepreneurial acumen, in an unfettered global market-place. (Brown, 1996:3)

The Fordist/post-Fordist distinction is not without its critics. Sayer (1989) for example, criticizes the concept of flexibility as too vague. He argues that the nature of mass production techniques is very different in different industries. For example, flexibility may not be a major criterion in industries involved in the manufacture of a particular kind of pen (Sayer, 1989:670). Therefore, flexible production techniques and the cost of a flexible labour force may not be applicable to all industries. Similarly, Williams et al. (1987:421) suggest that post-Fordist production techniques create the impression that there will be an automatic shift away from mass production. They argue a) that there is no evidence of this, and b) that a shift away from mass production would largely depend on the industry. For example, while Fordism was dominant in the electrical industry (e.g., cars, stoves, etc.), production in these industries have not stagnated. Furthermore, a vast range of 'new' goods (e.g., compact discs, cellular telephones, palmtop computers) are profitably being introduced to mass markets. However, many of these items are assembled in newly industrializing nations often along Fordist-style assembly lines, and usually by low skill, part-time (flexible) workers who enjoy little job security (Williams et al., 1987:421). It is criticisms such as these that have, in recent years, lead scholars to distinguish between post-Fordism and neo-Fordism as different models of economic development. Brown and Lauder, for example, suggest that the following principle be used to make this distinction:

> Neo-Fordism can be characterized in terms of a shift to flexible accumulation based on the creation of a flexible workforce engaged in low-skill, low wage, temporary and often part-time employment. Alternatively, post-Fordism is based on a shift to 'high-value' customized production and services using multi-skilled and high-waged workers. (1995:20)

It is argued here that the post-/neo-Fordist models of economic development pose some interesting challenges for South Africa. At a time when South Africa is negotiating its participation in a computer driven world economy, the post-/neo-Fordist distinction provides a useful framework for future development. It is argued here that the specific model of economic development that will eventually emerge in South Africa must take cognizance of domestic economic and social conditions as well as domestic expectations. Ultimately, it is these conditions that determine the basic rights of workers in industry, the adaptability of social institutions to new global challenges, and most importantly, the ability of South Africa's human resources to cope with the industrial and labour changes that comes with the introduction of new technologies.

Education-related reason

The third reason why it is considered desirable to develop and nurture an interest in science amongst citizens, relates to the relationship between economic development and education. Clearly, a model of economic development which emphasizes 'high-value' customized services, and which relies on a large multi-skilled labourforce, will have very different educational implications to one concerned with market flexibility, but which distinguishes between a small skilled managerial group and a large, low-skill, part-time labourforce. In the case of the latter (neo-Fordist) paradigm, Brown and Lauder (1995) argue that academic excellence is likely to be defined in individual terms, that is, 'survival of the fittest'. They explain that academic standards will increasingly be linked to the creation of a "market" of competing educational institutions. By creating a variety of public and private educational institutions between which individuals may choose, educational institutions become competitive and as a result, education standards are automatically raised. Furthermore, the freedom to choose between a variety of institutions allows individuals to make conscious decisions about subjects and educational choices, which may take into account constantly changing demands for labour (Brown & Lauder, 1995:23-24). What, however, about education in a post-Fordist paradigm? Earlier, it was suggested that in a post-Fordist economy, teamwork, cooperation, reasoning, communication and decision-making were examples of the kinds of characteristics likely to become basic features of its labourforce. This being the case, one could argue that the development of these skills should certainly be one of the general aims of education in a post-Fordist economy. It is not surprising, therefore, that scholars proposing a post-Fordist model of education warn that the creation of a variety of educational institutions as proposed by the neo-Fordist model has the potential to polarize the education system in terms of social class, ethnic minorities, religious sects, and so forth, particularly given that not all social groups enter the educational system as equals. As a result, it is likely that more affluent groups gain the advantage in the competition for credentials (Brown & Lauder, 1995:24). Consequently, post-Fordist models of education often promote the concept of ‘collective intelligence’ and a need to

> stop thinking about excellence in elitist terms. Excellence should be defined in terms of the collective skills, knowledge and know-how which can be deployed within society as a whole. … Sustainable economic growth will increasingly depend on the collective efforts of executives, managers, researchers, teachers, child carers, shopfloor workers, etc., because significant technological advances are rarely the result of the efforts and insights of any one person. (Brown and Lauder, 1991:20)

It is argued here that the concept ‘collective intelligence’ has vast potential for South Africa, particularly in the context of educational policy transformation currently taking place. Firstly, it provides support for the creation of educational systems that are based on the principle that **all** citizens are equally capable of academic achievement—particularly appropriate in post-apartheid South Africa. Secondly, it is a model that opens up the science classroom to influences from other sources, such as, for example, professional scientists sharing their views, holiday job opportunities in science-related industries, parent participation in school science projects and so forth. Thirdly, Pedretti (1997) argues that as South African classrooms become more racially integrated, the science curriculum will have to connect with the experiences of a diverse multicultural population. Curriculum reconstruction will, therefore, have to consider how issues of power, knowledge, vested interests, and moral positions influence the way in which learners interact with science (Pedretti, 1997:1212).

A key assumption of making a case for promoting science education is that as learners’ interest in science increases, so will their levels of academic achievement, and so will the number of learners capable of obtaining the academic standards necessary for entry into tertiary education and training systems. This is particularly important, given the growing concern about the *technical competence* of South Africa’s human resources. Gelb (1991), National Education Policy Investigation (NEPI) (1993), and Freund (1992) explain that South Africa does not have, in world terms, a well-established manufacturing or industrial sector. Historically industrialization in South Africa has largely been based on import substitution, that is, high quality and technological goods are imported rather than manufactured internally.[2] To improve its manufacturing sector, it is often suggested that South Africa concentrate less on the export of primary goods and more on beneficiation, that is, adding value to primary products by processing them locally for local markets, and then trading these manufactured goods on world markets for profit (Freund, 1992:8; NEPI, 1992:7). However, beneficiation requires a technologically and scientifically oriented workforce able not only to identify and exploit market niches, but also to select, design, plan and oversee the manufacturing processes that are increasingly edging closer to state-of-the-art science and technology.

The Centre for Development and Enterprise (CDE) argues that South Africa "cannot hope to develop these technologies—or even to productively apply technologies developed by others" (2004:5) as it lacks a sufficiently large group of citizens with a sound mathematics and science education. Furthermore, they argue that there is little evidence that this status-quo is likely to change sometime soon as the "maths and science education system is failing to deliver enough school-leavers equipped with HG [Higher Grade] maths and science to meet the country's needs" (CDE, 2004:5). In their recent assessment of mathematics and science teaching in South Africa, the CDE reports that for the period 1991-2003 the number of learners who enrolled for Grade 10 to 12 higher grade mathematics, which is essential for entry to many tertiary institutions, dropped from 53631 to 35959. Similarly, for Physical Science, the higher grade enrolment increased only marginally from 50954 to 52080. Often, such statistics are used to demonstrate the challenge that the establishment of a large skilled South African labour force faces. However, Sharwood (1990) takes a more realist approach by arguing that "the supply of labour is a function of the growth of the population" (1990:177-178). If, therefore, participation in a technologically-driven world economy necessarily means an increase in South Africa's manpower needs, then South Africa will have to ensure that the future labour force (which will come from our young "black" population) is adequately prepared to fulfill the country's future technological and scientific labour needs (Sharwood, 1990:178). This being the case, then South Africa's performance in large-scale systemic studies conducted in recent years suggest that a national crisis has developed in mathematics and science education. For example, in 2002, a national average score of 30% for numeracy at Grade 3 level was reported by the DoE (cited in Reddy, 2006b). More recently, in TIMSS 2003, which tested the mathematics and science proficiency of

[2] The cost of imported manufactured goods has been high (and not covered by SA's major source of income viz. the export of primary goods (e.g., minerals)). Also, goods manufactured in South Africa rely too heavily on foreign technology—again bought at a very high cost (Pouris, 1989).

Grade 8 learners, South Africa came last of the 50 countries who participated (Reddy, 2006a). These statistics suggest that an urgent investigation is required into measures that will speed-up the educational restructuring processes that are already in place in South Africa.

Summary

In this chapter, three reasons were offered as a justification for why it is desirable to develop and nurture an interest in science amongst South Africans. The first reason, related to issues of empowerment. It was argued that by taking an interest in science, citizens were more likely to be encouraged to actively participate in decisions on how science and technology is used in bringing about change to their lives. The second reason why it was considered desirable to develop an interest in science amongst citizens, related to the implications that improvements in computer and communications technologies have for labour. It was argued that in a technologically driven world economic environment the demand for a labour force which is numerate, has a basic level of skill in elementary statistics and some understanding of the principles of science and technology will increase. The implications that this has for the provision of science education in general was finally considered. It was argued that South Africa's shortage of citizens with sound mathematics and science education places a question mark on our ability to adopt new technologies and to utilize them in bringing about change. It was further suggested that there is an urgent need to speed up the educational restructuring processes that are already in place in South Africa.

Chapter Three

HOW LEARNERS INTERACT WITH SCIENCE

Introduction

In the previous chapter, it was argued that South Africa has a moral obligation to prepare its citizens for life in a world that is increasingly changing due to scientific and technological developments. The arguments made in support of this viewpoint were linked to the view that South Africa's economic participation in an increasingly technological world has implications for the personal and working lives of its citizens. It was further argued that democracy is also about contributing to decisions regarding how technology should be used in improving one's life, and that the ability to make informed decisions is linked to an adequate level of science education. This being the case, there is, in my view, a strong justification for focusing our attention on the factors that are likely to motivate peoples' interests in science and technology. Thereby, we create a cultural climate positive towards scientific and technological development in peoples' wider social, economic and political contexts.

For most South Africans much of their formal mathematics and science knowledge is acquired while they are in the schooling system. It is not unreasonable to assume that it is during this period that learners are most likely to develop an enthusiasm for, and general interest in, science. To a large extent, the various education policy and school-curriculum reform initiatives described in the previous chapter are aimed at improving the overall level of scientific literacy of South African learners. These initiatives are based on the view that competency in school mathematics and science will open up opportunities for access to higher education, higher skilled jobs, empowerment through better understanding of technology and a better livelihood. However in recent years, research has shown that learners are not influenced positively towards science by their in-class science experiences alone. Increasingly, it is being argued that factors in the informal milieu of learners influence what they choose to study at school and the careers choices that they later make. This chapter reviews what these factors may be. The first part of the chapter reflects on the view that how learners interact with science is influenced by their cultural and social contexts. In the second part of the chapter, several models of influence are used to demonstrate the multiplicity of factors thought to influence the learners positively towards science during their schooling years.

How learners interact with science

Over the past two decades, the impact that new technologies have had on the provision of science education in general has been the focus of much research. Consequently, Jegede, Naidoo and Okebukola suggest that

> in science education circles, the second millennium, in retrospect, would stand out as a period in human history characterized by a number of milestones. … Such milestones include science curriculum reforms; the search for exemplary teaching and best practice; understanding how students learn, conceptual change and prior knowledge; constructivism and the emergence of worldview and sociocultural studies. (1996:67-68)

Indeed, Dzama & Osborne (1999) argue that industrial and technological development has provided the impetus required to inspire students in Malawi to take an interest in science. They argue that by popularizing science and by creating a demand for scientific and technological careers students have begun to view science and science learning as worthy of the effort that it demands (1999:401). The views of Dzama and Osborne (1999) appear however, to be in contradiction to the views of scholars such as Jegede (1997, 1998), Ogunniyi (1988, 1997) and Lewin (1995) who are driven by concern about the way in which science education is experienced in non-western environments. Jegede (1998), for example, argues that if "science is a human attempt to understand nature every culture has its science and scientists" (2000:156). This view fits in with the constructivist epistemologies which emphasize that science is a human product, non-neutral, that we use it to build representations of our world, and so structure our how we act and communicate. Hence, science needs to be appropriate to the context in which it is used but there also needs to be a sense of history as it is not possible to assimilate scientific notions unless we are aware of the context which justified its creation (Fourez, 1995). Yet, Jegede argues that the way that science has been, and continues to be, taught in Africa, project a western world-view which claims to be superior to any other form of studying nature (1997:4). By applying western models of education in Africa, the worldviews that learners in different cultures have—which should reflect their views about what science constitutes, its meanings and goals—have been ignored. This being the case, it is argued that western models of education, as applied in Africa, are counterproductive to the learning of science because they do not identify with context-specific issues relating to what science should do for different communities. Consequently, there is no need to relate science to the out-of school environment of learners (Jegede, 1997; Ogunniyi, 1988). Jegede (1998) therefore suggests an approach to science teaching which acknowledges that

> The knowledge base for science and technology consists of the conceptual, skill, social, and resource domains. The conceptual domain is built by using pupils' background experiences, devising relevant examples and linking learning with the dominant cultural world-view. The skill domain is developed by creating opportunities for learners to use the process skills of science. The social domain is developed by involving learners as active members of the scientific community through group work and communication using appropriate reporting. The social domain is built by exposing students to real problems and encouraging innovative responses. Finally, the resource domain is built through access to appropriate materials for exploration and interpretation. (1998:154)

The simple summary of the work of Jegede (1997) and Ogunniyi (1988) provided above, became the basis of my understanding of studies concerned with the experiences that learners bring to science classrooms. For example, Kent and Towse (1997) examined the perceptions that junior secondary school learners in Botswana and Lesotho have of science and technology. Their research highlighted some interesting views. For example, when asked about their perceptions with respect to the teaching of science and technology activities at school, learners highlighted the "need for skills to cope with the modern world because it is full of technology" (1997:165-166). They also held the view that the value of science and technology education should be "considered in broad socio-economic terms, enabling people to cope in the modern world and gain employment, with the emphasis on the development of human capital for individual, local and national needs" (1997:165-166). With respect to attitudes relating to science & technology as a study for both boys and girls, learners supported the notion of equity of entitlement in such views as "boys and girls should have the same chance of getting exposed to the new ideas" (1997:166). Few respondents believed that the "emancipation of women would introduce conflicts into traditional beliefs such as girls should stay at home and look after the family (1997:166). The need for every citizen to "have a hand in the development of the country despite their sex" (1997:166) was also highlighted. With respect to the effect of science and technology on the home, the village and the country, science and technology was "overwhelmingly regarded as having improved the home from its construction and maintenance to the provision of utilities" (1997: 168), while tractors, tarmac roads and piped water have made their lives easier. However, females were "considerably more conscious than males of the benefits which technology has brought in health, hygiene, safety and social welfare" (1997:170).

On reflection, these results may be used to tell us a number of things. Firstly, we could say that they reflect a picture of a society not extensively permeated by science and technology. We could also say that in terms of the distinction that Fourez (1995) makes, science and technology in this context would probably be expected to "place itself at the service of progress" (Fourez, 1995:29), relevant to everyday life and be aimed at guiding humanity to a better future. Kent and Towse (1997) use these results to point out that significantly few references were made by respondents to improvements in indigenous technologies. This, they suggest, lends support to a widely held view that people in developing countries have laid <u>no</u> claim to technology that they call their own—technology is seen in terms of the products brought in from the developed world.

It is my view, however, that we could also argue that the extent to which the societal and cultural background of learners who participated in this study is reflected in their attitudes, takes us back to the view of Ogunniyi (1988) and Jegede (1997; 1998), namely, that science education must relate science more closely to the learner's societal and cultural environment. In doing so, we must expect that science educators will be confronted by different views of the world that learners have. Consequently, current attempts to popularize science and technology must consider how the background influences of learners affect how they respond to, and interact with, science and technology. Similar sentiments are reflected in the work of Ramsden who argues that

> For most pupils, much of their formal experience of science is likely to come about through their science lessons at school, where they will engage in a variety of activities structured in such a way as to give them some appreciation of scientific concepts and methods of scientific enquiry. Outside school, pupils may also participate in a number of different activities or hobbies which could be classed as scientific. In addition, they will certainly receive a variety of other messages about science, not only from their experiences in science lessons, but from sources such as the media, books, friends and relatives. These messages will relate to who scientists are, what sorts of jobs they do, how they behave, and what effects scientific activity have on everyday life. Thus the overall picture pupils gain of science, and the ways in which they respond to it, will be influenced by their experiences in school and outside school. (1998:126-7)

Several studies (Ainley, 1993; Atwater, Wiggings & Garder, 1995; Cleaves, 2005; George & Kaplan, 1998; Schibeci & Riley, 1986; Woodward & Woodward, 1998; Woolnough, 1994; Woolnough et al., 1997) concerned with how learners interact with science focus on factors mentioned by Ramsden (1998) above. What these studies show, is that by including outside experiences, it becomes difficult to pinpoint what exactly encourages learners to continue on to scientific and technological careers. For example, Entwistle and Duckworth (1977) suggest that different theorists may provide very different explanations. These explanations include, for example, that educators may stress the importance of teachers in influencing career choice (e.g., Robertson, 2000; Woolnough et al., 1997); sociologists may argue that in different societies young people are socialized into different roles and these are also reflected in career choice (e.g., Atwater, 1996); and psychologists may stress cognitive and personality differences in individuals (e.g., Collings & Smithers, 1983). While such arguments often sound persuasive, Entwistle and Duckworth (1977) point out that career choice is often influenced by the school subject choices that learners make. They argue that explanations offered by discipline-specific theorists, therefore, often ignore, firstly, that learners have to make decisions on subject choice very early in their lives, and, secondly, that these decisions are "likely to be affected by the constraints and opportunities provided in the educational system" (Entwistle & Duckworth, 1977:64). While Jones (1973) tends to support this view, he suggests that the path that a learner takes in his/her school career is a process of "selection and socialization" (1973:8). Agents function as filtering mechanisms by allowing only certain types of learners to move through the various layers (i.e., primary, secondary, post-secondary, tertiary) of the education system. Jones (1973) makes a distinction between direct socializing agents (e.g., peers, parents, school) and indirect socializing agents (e.g., authorities who design the curriculum, and the job market which defines the characteristics that school leavers should have). However, Jones adds that the products of the education system are not to be measured simply in terms of the number of school leavers. For example, in industrial societies, the type and level of qualifications may become important issues. In such circumstances we would extend our examination of agent effect to include how other factors (agents) influence the various subject choices that learners make (Jones, 1973).

Examples of models of influence

Nuttall (1990) points out that “an educational indicator tells something about the performance or behaviour of an education system and can be used to inform educational decision making” (1990:328). Indicators must provide “information about features of the system known to be linked with desired conditions and outcomes. This information can help policy-makers, educators, and the public predict future performance” (Nuttall, 1990:328). If, as Jones (1973) suggests, the products of the education system are not to be measured simply in terms of the number of school leavers, then we have to explore what other educational indicators will provide useful information about the research question being posed. For example, George and Kaplan (1998) investigated how parents and teachers influence the science attitudes of Grade 8 learners. In formulating their model of influence, George and Kaplan suggested that “what teachers do in the classroom is important, because science class experiences influence science attitudes. Also, parental involvement in the form of participation in the child’s education—by discussing school activities and encouragement of science activities—has an effect on student science attitudes” (1998:98). The exogenous variables of interest included science facilities in schools; teacher preparation; family structure; and the level of education of parents. The endogenous variables of interest included science experiments (teacher demonstration and learner participation in science experiments); parental involvement (learners’ perception of parental support for class and school activities); home resources (availability of learning resources in the home, such as books, encyclopedias, computers); visits to a library or to a science museum visits; and participation in extracurricular science activities such as a science fair or club. The final dependent variable in their study is science attitude which was measured as the enjoyment of science and the perceived importance of science for the future (George & Kaplan, 1998:98). The analysis of their data showed statistical significance in the following parameters. The availability of science facilities in schools had a direct effect on the amount of science experimentation in science classes and teacher demonstration. A significant direct effect of science activities on science attitudes was also found. The social aspects of science—group activities, open-ended laboratories and a visit to a science museum—are what learners enjoy. Participation in such activities has significant influences on learner’s attitudes towards science. Parental education was found to indirectly affect the extent of parent involvement. Higher parental education was associated with learner participation in science activities mediated through science activities such as visits to libraries, museums, science fairs and clubs. These activities have significant positive indirect effects on learner science attitudes. Based on these results, George and Kaplan (1998) argued that parents can foster positive attitudes towards science in learners by encouraging participation in extra-curricular science activities. Furthermore, improving the quality of science instruction and science activities in schools will indirectly affect the science attitudes of learners (George & Kaplan, 1998:100-104).

The model of influence postulated by Schibeci and Riley (1986) takes a more expansive look at learners’ background variables. In their study of 17-year olds, the influence of parents' education, sex, race, home environment and the amount of homework on (three dependent variables) learners' perception of science instruction, learner attitudes, and learner achievement was examined. In formulating their model of influence, they suggested that learners' background influence their perceptions of science instruction, and these in turn influence their attitude towards, and achievement in, science. Their aim was to make a causal inference that perception of instruction influence attitudes, and that these, in turn, influence achievement. They acknowledge that some background variables such as, for e.g., home environment, do not remain stable over time and, therefore, that their results must be treated with caution. Nevertheless, they conclude that gender and racial background was an influence on achievement, with females scoring lower and whites scoring higher, respectively. Home environment, homework and parent's educational background also had a substantial influence on achievement. Lastly, they conclude that

> what science teachers do in the classroom does make a difference in student attitude and achievement. … Assuming that student perceptions of their instruction are valid indicators of teaching behaviour, then teachers who exhibit such instructional behaviours as encouraging students to be creative and trying to make science more exciting are more likely to have a positive influence on student attitudes. These attitudes, in turn, can have a positive influence on student achievement. (Schibeci & Riley, 1986:185)

The model of influence postulated by Oakes and Guiton (1995) add an interesting and relevant dimension to the views of George and Kaplan (1998) and Schibeci and Riley (1986) presented above. They argue that high school tracking procedures often explain the "decisions" that learners make in their schooling careers. Consequently, it is important that we question how learners track along different subject paths, how schools decide what courses to offer, and how schools place learners in study streams. In their research on the impact that high school tracking has on learners' curriculum opportunities and outcomes, Oakes and Guiton (1995) questioned why low-income and minority learners (in the U.S.) are more likely to be in low ability classes for the non-college bound. As the subject choices that learners make in senior secondary school are important for shaping their occupational futures, differences in subject choice patterns may be seen as involving issues of equity amongst social groups. In their study, located at three senior high schools in the USA, Oakes and Guiton (1995) found that white and Asian learners had consistently better access to courses that lead to college and higher status jobs. This, they found was related, in part, to the type of curriculum offered at a school in a more advantaged neighbourhood and from the placement of these learners in a high track class (1995:28). Oakes and Guiton (1995) point out however, that teachers do not mechanistically sort, or blatantly discriminate against learners. “Students and their parents also played an active role … more advantaged parents took advantage of the waiver policy that permitted students to move into higher tracks. All students were given choices about elective courses and they were permitted to opt for easier academic courses” (Oakes & Guiton, 1995:29). The fact that learners from low-income households opt not to register for these courses could, Oakes and Guiton (1995) suggest, reflect a lack in confidence in their ability to manage difficult courses. Furthermore, vocational courses may be viewed as a safety net for joblessness, should college or post high school training not be possible. Follow-up interviews and observations revealed that while teachers may not mechanistically sort learners, schools accept these choices and only rarely pressed learners from low income households to stretch beyond their expectations (Oakes & Guiton, 1995).

In formulating his model of influence, Ainley (1993) argues that Australian learners also often find their subject choices constrained by the subjects on offer, the way the school timetable is structured, rules governing subject selection, and the nature of previous studies (1993:208). However, he suggests that the subjects that learners study in senior secondary school are affected as much by interests and aptitudes as by opportunities. Consequently, in his model of influence, he attempts to introduce a more broad spectrum view. He suggests that in addressing differences in subject choice among social groups, we need to look at competencies, interests, and patterns of choice, as well as how these interact with each other and with learner background variables (Ainley, 1993). In his study, Ainley (1993) explored the extent to which differences in participation in mathematics and science in senior secondary school learners in Australia arise from earlier interests and to what extent it is associated with differences in personal, social and school characteristics. Based on this research he argued that

> participation in a physical science course type is strongly associated with high levels of earlier schools achievement in numeracy and gender whereas participation in a biological and other science course type is more strongly associated with social background and curriculum influences. In addition … the low participation by females in physical science courses should be interpreted in terms of an interactive influence of gender, earlier achievement and socio-economic background. (Ainley, 1993:207)

In my view, these results demonstrate that not one single factor is all-important, and that in fact, there is a multiplicity of factors that influence the way in which learners interact with science. In isolation, the studies presented above may create the impression that it is possible to establish a single ‘best practice’ or ‘best influence’ which is universally effective. In reality, we know that individual learners’ are different, and that the structural school environment that learners find themselves in varies tremendously. This suggests that our explanations of the factors that influence the choices that learners make must blend individualistic, cultural as well as structural influences. In the following section, the work of Woolnough (1993) is introduced as one example of an approach that encompasses a more broad-spectrum view. In formulating his model of influence, Woolnough (1994) hypothesized that a learner’s “choice would be affected by their ability and personality, by the experiences they had in school and out of school, and by the value that society placed on careers in science and engineering” (1994:660-661).

Woolnough (1993) argued that if one of the reasons for teaching science in schools is to encourage some learners into higher education or careers in science and engineering, then the number of learners who actually do so can be regarded as one measure of the schools success. In a questionnaire administered to the Heads of school science departments at 80 schools across Britain, Woolnough (1994) sought details of the number of learners who went on to higher education in one of the physical sciences or engineering. He then sought information on the organisation of, and resources for, science within the school with respect to time, funding, laboratories and staffing. Secondly, he investigated the type of science activity that the learners were experiencing in the school. Using a Likert scale he assessed the teacher-centredness” (with the teacher directing the learners activities proscriptively) or learner-centredness’ (with the learner taking responsibility for their own planning and learning) nature of these science activities. Lastly, he asked the teachers, as expert witnesses, for their view on why learners were influenced toward, or away from, further study in science and engineering (Woolnough, 1993).

In his analysis, Woolnough (1994) sought to find correlations between “schools’ success” and the school factors listed above. Results of the study showed that there was a positive correlation between schools success and school resources, particularly the provision of laboratories, and in particular at schools with an engineering bias. Also positively correlated with success and engineering bias was the quality of the science teaching staff (i.e., the percentage of staff who were science or engineering graduates). With respect to the type of science activity which learners experienced at school, Woolnough's (1994) results showed that "schools with an engineering bias correlated positively with a more teacher-centered teaching style, more structured teaching, more structured notes and worksheets. Schools which biased learners towards the pure physical sciences correlated with a more learner-centered approach, in which they have more opportunity to experiment and plan their own activities" (Woolnough, 1993:115). The presence of science-related extra-curricula activities had a high positive correlation with the success of the school, but again, more so with future engineers. "Science clubs and competitions, the suspending of the schools timetable for project activities, and the support of parents and local engineers for the school science staff, all had a positive correlation with the schools success in sending learners onto higher education (HE) to study one of the physical sciences or engineering" (Woolnough, 1993:114). Finally, in his analysis of what teachers believed encouraged learners to continue with further study in science and engineering, Woolnough identified several common themes. The quality of teaching and the ability to give good career advice was considered important. Also key was a committed science department at the school and general support for science from the school itself. The practical or problem-solving nature of science activities, as well as the positive feedback provided by good exam results, was thought to motivate learners to continue with science. Non-school factors believed to have a positive influence were contact with real-life examples (e.g., guest speakers), exposure to science competitions and industry, open days, actual work experience and sponsorship for HE courses and the possibility of a "good, secure, interesting job later" (Woolnough, 1993:116).

Factors believed to influence learners negatively include bad teaching, thought to be the result of inadequately qualified teachers in both mathematics and science. Teachers also recognized that heavy teaching loads negatively affected their classroom effectiveness. An overwhelming number of teachers thought that learners were put off science because of the perception that science is dull and/or difficult. Teachers at girl schools thought that the practical nature of science made it unfriendly and unexciting for girls. Consequently, the way that learners saw future prospects for careers in science with respect to ease of entry into higher education, and possibilities for sponsorship, were considered important. Finally, teachers believed that learner's home background, parental expectations, personal ability and aptitude were playing an important role (Woolnough, 1993).

Based on these results, Woolnough hypothesized that the subject choices that school learners make may be affected by “their ability and personality, by the experiences they had in school and out of school, and by the value that society placed on careers in science and engineering” (Figure 3.1) (1994:659-661). Subsequent to developing this model, Woolnough (1994) tested his hypothesis in 1991, using a survey questionnaire which he administered with 1180 A-level learners across Britain. Learners were chosen from fifteen ‘successful schools’. Learners had not necessarily actually made a final decision to study science after completing school.

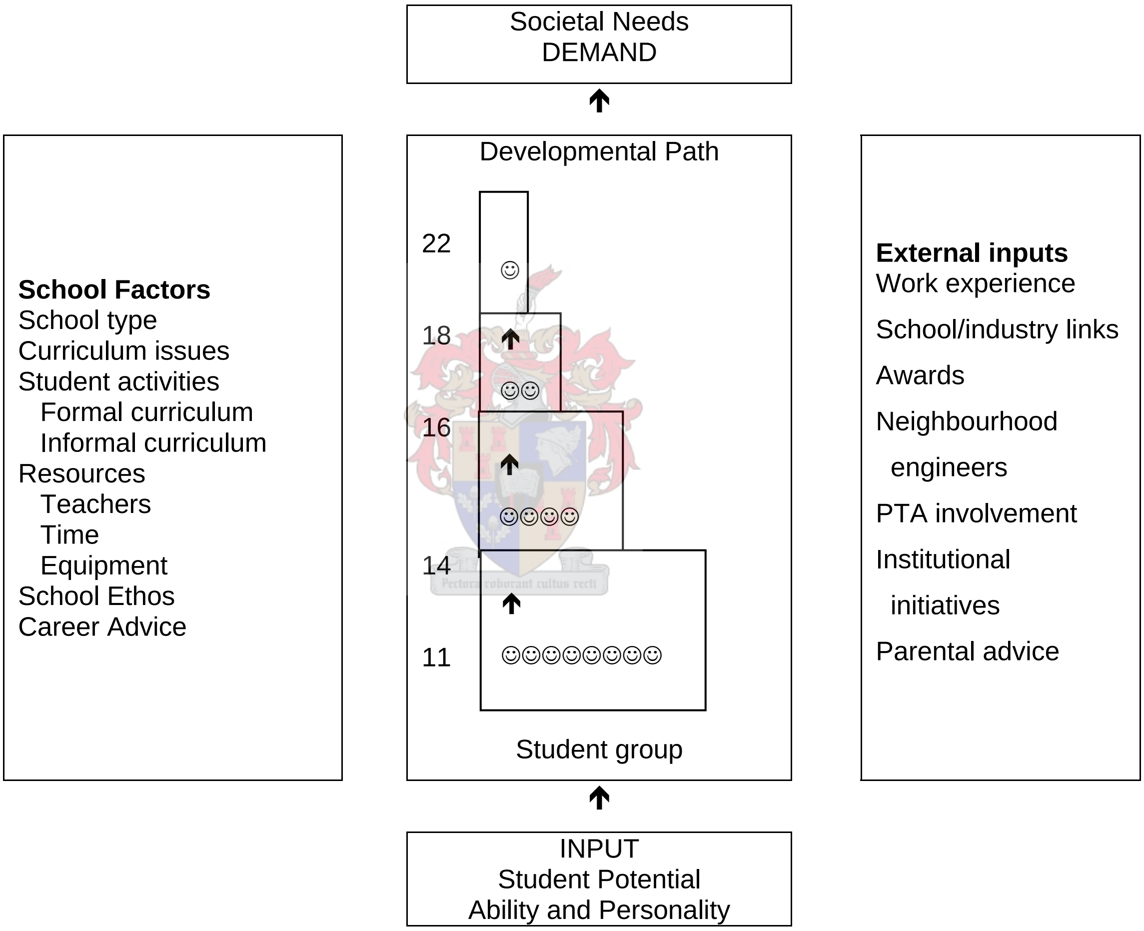

Figure 3.1. Woolnough’s hypothesis of factors that affect “the making of engineers and scientists” (1994:660).

Woolnough’s (1994, 1995) questionnaire examined learners’ home background, their school leaving subjects, whether they intended to pursue HE study and, at what point in their school career they had made this decision. He also examined learners’ attitudes towards different types of activity that learners met in their science lessons at school. Learners were asked to indicate which activities they preferred by responding to a Likert grid of statements. Statements related to whether activities were teacher-directed or learner-centered in relation to their experimental work, investigations, lesson plans, note making and work assessment. A further set of statements referred to learners' participation in extracurricular science activities such as science clubs, projects, competitions and links with local engineers. The actual factors—both-in-and-out-of-school—that learners felt encouraged or discouraged them in their decision about science or engineering were also examined. Using a Likert scale learners were asked to respond to descriptions of possible factors influencing choice, by indicating each to be encouraging, neutral or discouraging. Statements were derived from Woolnough's earlier survey of Heads of Science Departments. Finally, learners were asked to rate themselves on various personality and personal attributes. In 1995, researchers in Australia, Canada, China, Portugal and Japan used Woolnough's (1994) instrument to conduct parallel surveys in these countries (Woolnough et al., 1997).

Several common themes emerge from the studies conducted in England, Australia, Canada, China, Portugal and Japan. Woolnough et al. (1997) describe teachers as more important than the curriculum they taught in attracting learners to scientific careers. The most discerning factors between potential scientists and those anticipating a non-science career were reported to include the quality of the science teaching and the intellectual stimulation of the science curriculum. Woolnough (1994) found that for a small minority of "academic" learners (usually boys), interest in, and enthusiasm for, science was motivated by the challenge presented by the mathematical and abstract aspects of science, particularly physical science, and the need to further explore this subject. Consequently, he suggested that science, (particularly physical science) taught by subject specialists, was more likely to be successful at stimulating interest in science However, the effect of teaching style on learners appeared varied. Woolnough (1994) demonstrated that there was some evidence that the future scientists prefer the learner-centered approach to a more structured, teacher-directed one. Within the scientist groupings the biologists show a greater preference for the teacher-centered approach, which the physicists dislike, while the engineers show the greatest preference for the learner-centered approach, with its projects and competitions and opportunities for individual planning.

In all countries, the effect of scientific hobbies and fiddling with gadgets at home was shown to be highly influential (Woolnough et al., 1997). This finding is supported by the findings of Robertson (2000). In her case study of the factors that influenced 157

Year 1 University of Strathclyde in Glasgow students to register for bioscience, students expressed the same sentiment although less so for females (Robertson, 2000:1214). Like Woolnough (1994), Robertson (2000) also found that success and interest, which they describe in terms of "general enjoyment or/and interest in science subjects and success in school" (Robertson, 2000:1216), formed the principal decision-making rationale of students.

Woolnough et al. (1997) highlighted the importance of home background, factors, as well as participation in extracurricular activities, as predictors of subsequent careers in science. Like Woolnough (1994), they argue that learners who leave the school system heading for HE in science or engineering are "able and have been influenced by a scientific home background, both in their attitudes towards science and their technical hobbies and skills" (Woolnough, 1994:675). For learners anticipating a career in the pure sciences, home background was shown to play a particularly influential role. For future engineers, extramural activities were especially important, with science clubs, participation in science competitions, and links with local industry through speakers, visits and work experience being shown to be especially influential (Woolnough, 1994:675). Interestingly, this seems to contradict the findings of Robertson (2000) where an equal number of bioscience students conceded that home background influenced their choice as those who reported no influence. With respect to extracurricular studies, Robertson's (2000) bioscience sample reported that attendance at a careers open day, advice from a university and, advice from careers staff in school all provided positive influences.

With respect to learners' attitudes towards scientific careers, Woolnough (1997) and Robertson (2000) report that learners describe careers in science as useful for solving the world's problems. Although they provide no detail as to how learners view these problems in the first place, this view seems to reflect similar sentiments as those of the Botswana learners who participated in the study by Kent and Towse, (1997). Furthermore, it suggests that for some learners, Fourez's distinction may be relevant, namely that science and technology "place itself at the service of progress" (Fourez, 1995), relevant to everyday life and be aimed at guiding humanity to a better future.

Summary

At the outset of this chapter, the work of Jegede (1997) and Ogunniyi (1988) was introduced to support the view that learners in differing contexts experience science in different ways. This then raised the question that if the influences of home and society are so diverse, to what are we to attribute the decisions and choices that learners make about how they interact with science? In the Kent and Towse (1997) study, for example, science and technology education was important to learners because of the "need for skills to cope with the modern world because it is full of technology", "to gain employment", to build better houses, to make lives easier through the provision of tarred roads and piped water, and for improved health and safety conditions (1997:165-166). These are contextually relevant factors which influence how learners interact with science in school and possibly, later, the career choices that they make. Furthermore, researchers like Ramsden (1998) suggested that school science lessons, hobbies, friends, books, the media, messages about what scientists do and how they behave, all influence they way that learners interact with science. Whether or not they pursue scientific and technological careers may be influenced by the effect that teachers and parents have on the science attitudes of learners (George & Kaplan, 1998), by the background of learners (Schibeci & Riley, 1986), by the opportunities and constraints provided by the curriculum offered and school tracking policies (Oakes & Guiton, 1995), and by timetable limitations and rules governing subject selection (Ainley, 1993). The model developed by Woolnough (1994) brought together many of the factors examined by these studies. In doing so, Woolnough (1994) provides a useful framework for where we might start to look for explanations for why learners decide to pursue, or shy away, from further study and/or careers in science. Based on the results of studies conduct in England, Australia, Canada, Portugal and Japan, Woolnough et al. (1997) concluded that if more learners are to be encouraged to continue on to careers in science and engineering, quality of teachers and their teaching; quality of the school science curriculum; the attractiveness of careers in science with respect to status, salary, the challenge and stimulation that extra curricula science activities provide; the influence of home background; and the attractiveness of higher education courses with respect to sponsorship, ease of access and so on, will need to be examined. The similarities of findings in the parallel international studies were intriguing as it suggested that aspects of Woolnough's (1994) model might be applicable to the South African context. Furthermore, the recommendations by Woolnough et al. (1997) with respect to the broad themes that need further investigation provided a useful focus for this study and the methodological decisions that were made. These are discussed in the next chapter.

Chapter Four

METHODOLOGY

Introduction

Earlier it was argued that South Africa needs to promote a cultural climate which is positive towards scientific and technological development. A case was made for identifying factors which will encourage South African citizens, particularly young people, to take an interest in science, to appreciate science, to enjoy science, and for some, to pursue a career in science and technology. In the previous chapter, several models of influence were presented that offered some insight into what these factors may be. The assumption that this study is based on arose out of the findings of the studies presented, that is, that the factors that encourage learners to pursue HE and/or a career related to science and technology are related to, amongst other things, their background, their school environment and their in-and-out-of school experiences of science.

Research setting

This study required school learners to reflect on their school science experience. Consequently, it could be argued that ideally learners should have been tested at the end of the last year of high-school, that is, in Year 12, or as soon as possible after matriculating. However, limitations with respect to human resources meant that visits to a large number of schools were impractical and, therefore, not an option for this study. It was decided, therefore, to access learners via a tertiary institution, but as early as possible in their first year of registration[3]. The decision to access students at university, as opposed to one or two schools only, relied on two assumptions. Firstly, that students entering university were likely to come from a more diverse background than if students were selected at one or two schools only. Secondly, accessing students within a school context provided no guarantee that students would actually go on to further study in science or engineering. Consequently, it was decided to focus on students who had actually made the decision to pursue further study in science and engineering (i.e., a self-selected group). Such individuals would be students who

- were in their first year of university registration, and

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[3] From this point onwards therefore, I will use the term (university) student, as opposed to learner, when referring to respondents. It is emphasized however, that students were asked to reflect on their science experiences while they were learners at school.

- who had been in their final year of schooling in the immediate preceding year and,
- who had registered for either a science or engineering degree

Successful application was made to the University of Cape Town, the most accessible tertiary institution to the researcher, to have access to first-time entering first year science and engineering students. It is acknowledged that restricting the study to a single institution limits the findings of this study in terms of its generalisability.

Research design

This study has features of both a case study and a snap-survey, although these are generally seen as two distinct research strategies (Wiersma, 1991). In line with definitions of a case study, this study is concerned with science experiences of one cohort of science and engineering students within a particular context, at a particular place and time. Miles and Huberman (1994) argue that case studies usually employ multiple methods of data collection in exploratory work. But this study was formulated as having essentially a descriptive purpose and a survey approach, is often considered to be more suitable for descriptive work. Consequently, it was decided to use a quantitative research design to conduct a snap survey of the profile a group of students who chose to study science or engineering at the University of Cape Town (UCT). The aim is to provide a picture of what the UCT science and engineering student looks like with respect to his/her personal background, school background, their in-and-out-of-school experiences of science and the factors that they thought most influenced their decision to study science or engineering

Although information generated by pencil-and-paper instruments are sometimes criticized as being superficial—they describe rather than explain—they are an efficient and cost-effective way of obtaining information from a large group of individuals (Macmillan & Schumacher, 1993; Robertson, 2000). Consequently, it was decided to use a structured questionnaire was used to collect data. Furthermore, in his analysis of the type of data collection tool which have been used to gather data on learners' affective responses to science and science lessons, Ramsden (1998) reports a "heavy reliance on inventories and scaling techniques" (Ramsden, 1998:130). A large number of interest or attitude inventories have been developed, commonly employing measurement scales such as Likert-type scales (Osborne, 2003; Ramsden, 1998).

The similarities of findings in the various international settings suggested that Woolnough's conceptual model and questionnaire might be relevant to, and appropriate for use in, the South African context. However, it was decided not to replicate Woolnough's (1994) study. The primary reason for this decision was that Woolnough's (1994) model was exploratory in nature. Students were tested while still in the school system. At the time of testing Woolnough (1994) could not tell for certain if they would actually go on to HE in science. His study explored possible factors of influence amongst students who thought they might go on to HE in science (and the questions used in his questionnaire were designed to probe these possible factors).

In this study, students had actually made the decision to study science and engineering. Consequently it was decided to focus on specific factors that the studies by Woolnough (1994) and others, actually showed were more likely to have influenced the decisions that students have made. For this purpose, several items used in the Woolnough (1994) questionnaire, particularly with respect to their school science experiences, were adapted for use in the questionnaire used here.

In the following section, the key attributes of the questionnaire used are outlined. The pilot testing phase, as well as the administration of the questionnaire, is then described. Finally, the final overall sample used in this study is presented.

Questionnaire used

The survey questionnaire used in this study consists of two sections. Section A relates to the views of Schibeci and Riley (1986), Oakes and Guiton (1995), Ainley (1993), George and Kaplan (1998), and Woolnough (1994), reviewed above. Here, self-reported data is sought in the following areas.

Students' background

Variables used here include *gender* which is self-explanatory. In this study, *language* was used as a proxy for race in the absence of a direct race indicator. It is recognised that a limitation of this approach is that one cannot assume that a student who speaks English at home is not African. However, Kahn (2004) suggests that where precise data cannot be obtained, an appropriate proxy will suffice and if appropriately chosen may be a valid and reliable basis for analysis (Kahn, 2004:156). *Year matriculated* was used to filter out students who did not complete matric in the immediate preceding year (a condition for participation in this study). *Name of school* was used to identify the feeder schools which “send” students to UCT and was not used in analysis.

Science subjects that students studied in matric

Students who participated in this study would not have been affected by the curriculum changes being introduced in 2006 in Grades 10-12, outlined in chapter 1. In terms of the South African matric regulations that applied at the time when participants were in matric, three science subjects was the maximum number a student could study in his/her matric year. Students decided whether to study these subjects on the higher or standard grade. The five Natural Sciences subjects widely taken in high school in South Africa are Agricultural Science, Biology, Geography, Physical Science and Physiology. For this study, Mathematics and Computer Science were not regarded as science subjects and were excluded. It was decided to focus on natural science subjects only, as students were asked to reflect on “universal” teacher’s instructional objectives such as, for example, conducting experiments, that are characteristic of teaching in the natural sciences in general.

Why students chose to study a science subject at school

In this variable, students were asked to consider the effect that several factors might have had on their school subject choices. The factors relate to the personal motivation (Woolnough, 1994) as well as structural influences that affect the choices that students make (Oakes & Guiton, 1995).

Year of registration

This variable was used to filter out students who were not in their first year of study (a condition for participation in this study).

Faculty in which the student is registered

The decision to distinguish between science and engineering was motivated by Woolnough’s (1994, 1997) study which concluded that potential scientists and engineers respond differently to different influences.

Career aspirations

Earlier it was stated as an assumption of this study that when students decide to pursue further study after school, they say something about their career aspirations. It was assumed that students who have chosen to study science and engineering at university will one day have a career in a science or engineering related field. This variable relates to specific career aspirations that students have. Of particular interest to this study was the number of students who thought that they might want to go on to become a Science Teacher. It is argued that the successful future development of a scientifically literate citizenry will rely on increasing the number of mathematics and science HG passes and on increasing the number of students who enter higher education. These, however assume a sufficient supply of mathematics and science educators.

Parent's occupation

Data provided for this variable was pre-coded. If a student's parents had an occupation that was directly related to science, engineering, technology or medicine it was indexed as such. All other occupations were coded as "none of the above"

The person who most influenced career choice

In this variable students were asked to identify from a list of possible relationships the person who had the most influence on their career choice.

Part-time job

This variable relates to whether the student had a part-time job that was directly related to science, engineering, technology or medicine while in his/her senior years of high school. Data provided for this variable was pre-coded. If a student had a part-time job that was directly related to science, engineering, technology or medicine it was indexed as such. All other occupations were coded as "none of the above".

Attitudes towards science

Data sought here aimed at establishing the views that students have of science in general. Students were asked to respond to a Likert grid of statements.

In the design of section B of the questionnaire, the work of Woolnough (1994) was influential. Here students' retrospective views on their high school science experience are sought. Students are asked to describe their high school science experience with respect to the facilities that were available at school, and the non-curriculum science related events which were organized by, or took place at, the school. Woolnough (1994) demonstrated that facilities such as the provision of careers information, access to a career guidance teacher and displaying students' science projects are desirable as they promote a general climate of interest in science at schools.

With respect to the classroom environment, items adapted from Woolnough (1994) sought students' retrospective views with respect to the nature of their science classroom lessons. Students were also asked to respond to a Likert grid of statements that relate to their preferences with regard to specific classroom activities.

A further set of statements (question 21) were built into the questionnaire as cross-check references. As a pointer to the reliability of students responses, students responses to selected items in questions 21, 17 and 14 were cross-checked for consistency of responses (for example, a agree/not sure/disagree answer to question 21 (b) must have a corresponding yes answer to question 17(a).)

In the final question, students were asked to consider whether specific factors had influenced their decision to study science or engineering.

Limitations and assumptions of the research design

It is acknowledged that because of the non-experimental nature of this study (i.e., no use is made of an experimental control group), it is not possible to make any inferences about cause-and-effect. The unit of analysis used in this study is the individual student. It is assumed that when answering questions, students give answers that accurately reflect their own position.

Pilot study

Before administering the final version of the questionnaire, it should be tested (or piloted) on a small group of respondents from the target population into order to identify potential ambiguities, as well as to uncover problems relating to the instructions for completion (Wiersma, 1991:177-178). The piloting phase of a study also provides an opportunity to revise the instrument and to make it as appropriate as possible for its designed purpose, to ensure that the questions being asked yield the information sought, and to ensure adequate reliability and validity of the instrument (Rosier, 1997:157).

The questionnaire designed for this study was piloted on 20 first-year, first-time-entering, engineering students all of whom were enrolled in the ASPECT (Academic Support Program) at UCT in 1999. ASPECT students fit the profile of students required for this study (i.e., they were first year science/engineering students) but do not enroll in the regular first year programme). The final questionnaire was not therefore presented to the piloted group. All twenty students volunteered to participate in the pilot phase of this study. The questionnaire was administered in a one-to-one setting between the researcher and the student. This was an ideal setting as it gave the researcher the opportunity to explain the purpose of each question to the student and thereby, to test the aptness of the instruction given at the beginning of each question. The respondent was encouraged to ask questions and to underline words which were not clear. After the completion of each question, the respondent and the researcher stopped to discuss possible problems and ambiguities relating to instructions given and/or questions and statements used in the questionnaire. Several minor instructional and editorial changes were made to the final instrument that emerged from the pilot process.

Completion of the questionnaire during the pilot testing phase took on average 55 minutes.

Administration of the questionnaire

Permission to access students was granted by the Deans of the Faculties of Science and Engineering at UCT. Departmental Heads were requested by Deans of Faculties to introduce the study to lecturers and tutors, who then liaised directly with the researcher regarding an optimal time to administer the questionnaire. The questionnaire was administered—always under the researcher's supervision—to first year science and engineering students at the University of Cape Town in 1999 during the first four weeks after registration. It was considered important to access students as close as possible to the "end" of their schooling career. The questionnaire was administered to seated students during the final half and hour of a normal tutorial/practical session. Lecturers and tutors remained present at the respective venues during the administration of the questionnaire at all sessions. Students were explicitly told by lecturers and tutors that their participation in the anonymous survey was completely voluntary, that the data would not be available to departments. In this way, the fear that non-participation might affect marks in the future was reduced. Students were asked not to leave the room and to remain seated until all questionnaires had been collected. At all venues, 100% cooperation was achieved in this regard.

In my introduction to students the general purpose of the survey was explained. The structure of the questionnaire was described and the importance of using the "not applicable" option where appropriate was stressed. It was stressed to students that this study was concerned with their school science experience and that all questions answered must be with reference to their favourite science subject (which could have been either, Biology or Physical Science or Geography or Agricultural Science or Physiology, etc.). Students were given the opportunity to ask questions about the exclusion of mathematics and computer science, and where required, the assumptions of the study in this regard were explained. I was present throughout the administration of the test and, therefore, available to answer questions. Completion of the questionnaire lasted approximately 30 minutes.

All questionnaires were checked to ensure that they had been completed correctly. Problematic or incomplete questionnaires were immediately discarded. Data from the questionnaire were subsequently captured into SPSS 13.0 for statistical analysis. This enabled me to capture all numeric and textual data. Cross checks were done by myself on a random selection of cases. Frequency tables on all variables were then computed, and the data set was 'cleaned' by myself using these tables. The frequency tables also allowed for identification of irregular responses within variables. In such instances, the original questionnaire was consulted and a decision was made about the continued inclusion of the record in the final dataset.

Overall sample

Mathematics I is compulsory for **ALL** first-year science students. The questionnaire was therefore administered to all first-year science students who were targeted through the various Mathematics I courses (i.e., MAM101W, MAM104F, MAM105H, MAM104H). A total of 407 students completed the questionnaire. Of these, 79 records were immediately eliminated because the student was not registered in the science faculty or because the record contained missing data (usually an incomplete questionnaire). These records were regarded as spoilt and never captured. A further 59 student records were eliminated because students had not matriculated in the immediate preceding year. A further 65 were eliminated as they were not first year students. The records for the two latter groups were captured but eliminated from the final analysed dataset. The sample of first-year science students on which the analysis in the following chapters is based is therefore 204 records (45% of the sample).

The questionnaire was administered to **ALL** first-year engineering students during compulsory tutorial sessions. A total of 376 students completed the questionnaire. Of these, 28 records were immediately eliminated because the records contained missing data. These records were regarded as spoilt and never captured. A further

54 records were eliminated because students had not matriculated in the immediate preceding year. A further 47 were eliminated as they were not first-year students. The records for the two latter groups were captured but eliminated from the final analysed dataset. The sample of first-year engineering students on which the analysis in the following chapters is based is therefore 247 records (55% of the sample).

In summary, a final sample of 451 records were included in the dataset used in this study (Table 4.1). The distribution of students within the courses sampled in each of the two faculties is represented in Table 4.1 below.

Table 4.1. Total number of students sampled per course. The number of students sampled in each course is also given as a proportion (%) of the overall sample size

Faculty	Courses sampled	Frequency	Percent
Science	Mathematics	204	45.2
Engineering	Civil Engineering	42	9.3
	Mechanical Engineering	44	9.8
	Electrical Engineering	97	21.5
	Chemical Engineering	32	7.1
	Surveying	5	1.1
	Materials Engineering	7	1.6
	Electro-mechanical engineering	20	4.4
Total		*451*	*100.0*

Summary

This chapter described the setting in which the research was conducted and well as the salient features of the questionnaire used to collect data. The piloting of, as well as the administration of the questionnaire was then described. Finally, the final sample used in this study (N=451) was introduced—204 Science and 247 Engineering students, respectively. In the following chapter, the results of the analysis of the data with respect to students' background, their school science experience, and their perceptions of the factors that influenced their decision to pursue a career in science and engineering are described.

Chapter Five

RESULTS

Introduction

In this chapter results of the analysis of data are described. These results are based on the quantitative analysis of students' responses to questions about their personal background, their school background, their in-and-out-of-school experiences of science and the factors that they thought most influenced their decision to study science or engineering.

In the analysis, questions in section A of the questionnaire were divided into two parts. The first, grouped key personal background attributes of the sample i.e., language, sex, career aspirations, the person who most influenced the student's decision to study science and engineering, parents' occupation and whether the student had a part-time job related to science or engineering while at school. The second, grouped key school background attributes of students with respect to the science subjects that they studied in matric, the reasons why their favourite science subject were chosen, and the size (i.e., the number of learners) of their favourite science class in their matric year. Descriptive statistics were used in the analysis of all variables in these sections. Results were analysed using the SPSS 13.0 package.

Section B of the questionnaire was concerned with students' high school science experience. Students' retrospective views were sought with respect to the type of facilities available at school, as well as the non-curriculum science-related activities and events which were organized by, or took place at, the school. With respect to the classroom environment, students' retrospective views were sought with respect to the nature of their science classroom lessons. Students were also asked to respond to a Likert grid of statements that relate to their preferences with regard to specific classroom activities. Finally, students' self-reported perceptions of the effect that aspects of their background, as well as their general experiences of science while at school, have had on their decision to study science and engineering were examined. As indicated in Chapter 4 (pg. 42), the total sample consists of 451 students. Specific individual analyses were performed on items in which variables of interest were all responded to. As some questions had missing responses, total number of students in the sample varies between 164 and 451.

Personal background profile of students

Home language

The majority of students in the sample (91%) speak one of the eleven official South African languages (Table 5.1). Nine percent of students speak an unspecified language at home. English was the home language of 55% of the sample. Only 4% of students speak Afrikaans at home. A further 32% speak one of the other nine official languages (i.e., African languages) at home (Table 5.1).

In order to undertake more fine-grained analyses, home language was used as a proxy for race in the absence of a direct race indicator. It was assumed that all students who have an African home language are African and that students who speak English and Afrikaans at home are non-African (i.e., White, Coloured or Indian). Consequently, 31% of the sample is characterized as African, 59% as non-African, and for 10% of the sample the race could not be determined in this way (i.e., students' home-language is not one of the eleven official languages).

Table 5.1. Home language distribution amongst the students sampled

Language	Frequency	Percent
English	249	55.3
Xhosa	34	7.6
Tswana	29	6.4
Zulu	24	5.3
Northern Sotho	21	4.7
Afrikaans	18	4.0
Southern Sotho	15	3.3
Swazi	6	1.3
Tsonga	5	1.1
Venda	5	1.1
Ndebele	2	0.4
Other	42	9.3
Total	*450*	*100.0*

Sex

Overall, the sample has a male bias—66% of the sample is male and 34% female. However, within the two faculties, interesting differences in the gender composition of students emerge. Within the male sample, 68% are registered in the engineering faculty and 32% in the science faculty, while within the female sample we have exactly the opposite trend (i.e., 70% is registered in the science faculty and 30% in the engineering faculty).

Career aspirations

As expected, 94% of the engineering students indicated that they expect to be working as an engineer in the future. Further analysis of this variable was, therefore, limited to science students only (Table 5.2). The major careers that science students wish to follow are a scientist (38%), computer scientist (26%), medical doctor (11%) and engineer (5%), which account for 80% of the science student sample (Table 5.2). Interestingly, only 1% of science students expect to go on to teaching.

More females than males aspire to becoming a scientist or doctor—only 3 out of 10 males indicated this as opposed to roughly 6 out of 10 females. For those who aspire to become a computer scientist, this trend is reversed with 7 out of 10 males reporting this as opposed to roughly 4 out of 10 females (Table 5.2).

Table 5.2. The number of female and male Science students with particular career aspirations. Percentage refers to the proportion of females/males per individual career choice

Career	Female Scientists		Male Scientists		Total	
	Freq.	%	Freq.	%	Freq.	%
Scientist	48	62	29	38	77	38
Computer Scientist	16	31	36	69	52	26
Doctor	14	61	9	39	23	11
Engineer	4	40	6	60	10	5
Lab Technician	4	67	2	33	6	3
Actuary	2	33	4	67	6	3
Science Teacher	1	50	1	50	2	1
Architect	1	100	0	0	1	1
Other	15	63	9	37	24	12
Total	*105*	*52*	*96*	*48*	*201*	*100*

Person who most influenced career choice

In rank order, the person who most influenced the students' career choice was their father, their mother, a career counselor, and a teacher; these individuals accounted for 57% of the responses (Table 5.3). An unspecified influence was stated by 15% of the overall student sample (Table 5.3).

For male and female students, differences in their selection of influential persons were noted. For example, while 16% of the female sample said that their mother was the person who most influenced their career choice, only 12% of the male sample indicated this. On the other hand, 25% of male students, as opposed to 19% of female students, selected their father as the person who most influenced their career choice. The proportion of male students who indicated a relative who is an engineer or scientist (9%) was almost double the female proportion (5%).

Table 5.3. Rank order of the person who most influenced the students' career choice for the overall student sample

Influence	Frequency	Percent
Father	94	23
Mother	54	13
Career's counselor	46	11
Teacher	41	10
Another relative	32	8
Relative with science/engineering	32	8
Friend	25	6
Scientist/engineer visited school	23	6
Other	62	15
Total	*409*	*100*

Investigating students' responses to the person who most influenced their career choice using race as a variable, produced interesting trends. Sixteen percent of African students said that their mother was the person who influenced their career choice most, as opposed to 11% of non-African students. However, while 16% of the African student sample also indicated that their father was the person who most influenced their career choice, 26% of non-African students indicated this. Eighteen percent of African students indicated that a careers counselor influenced their career choice, but only 9% of the non-African sample who indicated this. Similarly, for African students, a teacher was indicated as having influenced the career choice of 14% of the sample, while only 8% of non-African students indicated this.

Parents' occupation

Table 5.4 shows the proportion of students' mothers and fathers in a science-related occupation (i.e., an occupation related to science, engineering, medicine or technology). Twelve percent of respondents' mother has an occupation in either science, engineering, medicine or technology whereas the corresponding figure for fathers is 24% (Table 5.4).

Table 5.4. The proportion of students' mothers (n=54) and fathers (n=110) in a science-related occupation in rank order per parent

	Mothers			Fathers	
Occupation	**Frequency**	**Percent**	**Occupation**	**Frequency**	**Percent**
None	397	88.0	None	341	75.6
Medicine	47	10.4	Engineering	51	11.3
Technology	4	0.9	Medicine	28	6.2
Science	2	0.4	Technology	24	5.3
Engineering	1	0.2	Science	7	1.6
Total	*451*	*100.0*	*Total*	*451*	*100.0*

When race is taken into consideration, a greater percentage of African students (18%) have a mother with a science-related occupation than non-African students

(9%); with regard to fathers the trend is reversed as only 5% of African students have a father with a science-related occupation in comparison to 34% of non-Africans students.,

In the case of mothers who do work in one of the above areas, the majority (87%) have a medical-related occupation. For students with mothers having a medical-related occupation, 56% are African and 44% are non-African. For fathers, 25% have a medical-related occupation while 46% work in the engineering sector. For fathers with an engineering-related occupation 11% are African and 89% non-African. More fathers work in the technology-related sector (22%) than mothers (7%).

Part-time employment

Less than 10% of the students in this sample had a job related to either science, engineering, medicine or technology while at school. When analysed by faculty, this translates into four percent of engineering students who had a part-time job in an engineering-related sector. Five percent of science students reported having a technology-related part-time job while at school.

School background profile of students

Class size

The key interest here was to gain insight into the number of students in this sample who were part of large science classes while at school—an environment generally thought to be non-conducive to effective teaching. Twenty six percent of the African student sample used in this study reported a class size of greater than 40 students in their favourite science class in matric as opposed to five percent of non-African student sample.

Science subjects taken in matric

The combination of science subjects taken in matric was computed, based on the six most common science subjects offered in senior high-school in South Africa (i.e., Biology, Physical Science, Geography, Computer Science, Agricultural Science and Physiology). Overall, seven science subject combinations account for the matric science subject selection of 86% of students sampled (Table 5.5). The two most common science subject combinations are Biology and Physical Science and

Biology, Physical Science and Geography. Interestingly, Physical Science appears in <u>all</u> of the seven most common science subject combinations.

Table 5.5. The science subject combinations taken by students in matric

Subject combination	Frequency	Percent	Cum. %
Physical Science and Biology	173	38.8	38.8
Physical Science, Biology and Geography	83	18.6	57.4
Physical Science only	39	8.7	66.1
Physical Science and Geography	30	6.7	72.9
Physical Science, Computer Science and Biology	23	5.2	78.0
Physical Science, Computer Science and Geography	17	3.8	81.8
Physical Science and Computer Science	17	3.8	85.7
Other combinations	64	14.3	100.0
Total	*446*	*100.0*	

Some differences are evident in the matric science subject combinations of science and engineering students. Whereas 44% of science students took Biology and Physical Science, only 35% of engineering students did so. The combination of Biology, Physical Science and Geography (i.e., the second most popular science subject combination) was taken by 23% and 15% of Science and Engineering students, respectively. The proportion of students who took <u>only</u> Physical Science in matric was 4% and 12% for Science and Engineering students, respectively.

Why students choose to do one science subject in matric

The three most common reasons for choosing to study at least one science subject at school are—in rank order—that students a) knew that they needed a science subject to have a career in science or engineering (67%), b) liked General Science in standards 6 and 7 and wanted to know more about science (54%), and c) thought that they might need a science subject to get into university one day (44%) (Table 5.6).

Table 5.6. Rank order of reasons given by students for taking at least one science subject to matric

Reason	Frequency	Percent
I knew I would need a science subject to have a career in science or engineering	304	67
I liked General Science in standards 6 & 7 and wanted to know more about science	243	54
I thought I might need a science subject to get into University one day	200	44
I always did well in mathematics and thought a science subject would be easy	132	29
I had no choice. The school decided which subjects I should do	35	8
My parents insisted that I do a science subject at school	23	5
All my friends did a science subject at school	12	3

Reasons for taking at least one science subject reported by less than 10% of students (i.e., the least frequent reasons) include that a) students' friends did a science subject at school (3%), b) students' parents insisted that they do a science subject in school (5%), and c) that students had no choice because their school decided which subjects they should do (8%) (Table 5.6). No statistically significant difference was found in how science and engineering students responded to this item.

Students' views of science in general

In question 15 (Appendix, pg. 89), students were asked to respond to statements that refer to their views of science in general. The mean score was calculated for each item (Table 5.7), using a score of 5 for Strongly Agree and a score of 1 for Strongly Disagree. Reverse scoring was applied to the one negative item—*Science is difficult and I really have to work hard at it*. By implication, a score of 1 was assigned for Strongly Agree and 5 for Strongly Disagree.

Overall, students' responses show that, with a mean item score of greater than 4, students agree that science is useful in every day life and that science is exciting and that they want to know more about it (Table 5.7). With an overall mean item score of 2 or less, students' responses show that they disagree with sentiments to the effect that science is difficult and that they have to work hard at it and with the view that science is more useful for boys than for girls (Table 5.7). Students were, however, unsure of whether they needed science to get a good job and whether scientists and engineers have more status in their community than people in other professions, as the mean score for these items was about 3 (Table 5.7).

Table 5.7. Mean scores for individual items that refer to students' views of science in general

Statement	N	Mean	Std. Dev.
Science is useful in everyday life.	450	4.40	0.643
Science is exciting and I want to know more about it.	450	4.08	0.746
I need science to get a good job	449	3.37	1.124
Science is difficult and I really have to work hard at it.	448	2.11	1.014
Science is more useful for boys than for girls	447	1.65	0.871
Scientists and engineers have more status in my community than people in other professions	450	2.92	1.028

Students' responses to individual items in question 15 were combined to form an attitude towards science scale with a maximum score of 30 (all items scored 5) and a minimum score of six (all items scored 1). By implication this means that a high score on the attitude towards science scale indicated a positive attitude towards science and a low score indicated a less positive attitude towards science. Mean scores were combined for different groups of students—statistically significant differences in students' mean scores on the Attitude Towards Science scale were found between African and non-African, males and females, and students studying science and engineering (Table 5.8). These results indicate that engineering, African and male students have more positive attitudes toward science than non-African, female and science students but the differences are very small and caution needs to be exercised when interpreting these results (Table 5.8).

Table 5.8. Statistically significant differences in the mean Attitude Toward Science score between students' of different faculties, races, and sex

		N	**Mean**	**Std. Dev.**	***t* value**	**df**	***p***
Faculty	Engineering	240	18.8	2.34	2.95	438	0.003
	Science	200	18.1	2.58			
Race	African	138	19.0	2.46	-3.35	396	0.001
	Non-African	260	18.2	2.31			
Sex	Female	150	17.9	2.43	-3.73	436	0.001
	Male	288	18.8	2.44			

School science experience

Responses to section B of the questionnaire (Appendix, pg. 90) are reported below. Questions in this section of the questionnaire sought to describe details of the characteristic features of the high school science experience of students. Particular attention was paid to the school facilities, the non-curriculum science related activities that were organized by, or took place at school and the nature of science classroom activities. Students' preferences with regard to specific science classroom activities were also examined.

School facilities

A summary, in rank order, is provided (Table 5.9) of the number of students who reported on the availability of particular school facilities. In this question, students were asked to indicate by ticking all facilities which were available at their last school. It is presumed, therefore, that items that were not ticked were not available. Overall, between 21% and 79% of students reported that they had access to one or more facilities at the school from which they matriculated. The vast majority of students reported that they had a careers guidance teacher at school (79%), and half or more of the sample reported the presence at their school of a well-equipped science and computer laboratories (65% and 49%, respectively). Roughly 4 out of 10 students reported that they had access to career information either via a notice board for careers information or a careers information library. Between a third and a fifth of students reported that the school had a notice board for interesting science material (30%), that students' science projects were regularly displayed (32%), or that there was an active science club at their school (21%).

Table 5.9. Rank order of the number of students who reported on the availability of particular facilities at their schools

Facility	Frequency	Percent
A careers guidance teacher	354	79
A well-equipped science laboratory	295	65
A well-equipped computer laboratory	221	49
A notice board for career information	187	42
A careers information library	172	38
A regular display of students' science projects	144	32
A notice board for interesting science material	134	30
An active science club or society	96	21

When race is taken into account in the overall summary provided in Table 5.9 some differences emerge. Responses to question 16 of the questionnaire (Appendix, pg. 90) were used to construct a 2 x 2 contingency table for each school facility, using race as an independent variable. These tables were analysed using Fisher's Exact Test (one sided) with one degree of freedom.

Table 5.10. Comparison of the availability of specific facilities at the schools of African and non-African students

Facility	Non-African		African		Chi-square	Sig.
	Freq.	%	Freq.	%		
A careers guidance teacher	226	85	99	70	11.6	***
A well-equipped science laboratory	198	74	71	50	23.3	***
A well-equipped computer laboratory	164	61	35	25	49.5	***
A notice board for career information	128	48	47	33	8.0	**
A careers information library	119	45	44	31	6.9	**
A regular display of students' science projects	97	36	39	28	3.1	*
A notice board for interesting science material	87	33	39	28	1.0	NS
An active science club or society	67	25	25	18	2.9	NS

NS $p > 0.05$
* $p < 0.05$
** $p < 0.005$
*** $p < 0.001$

The proportions of African and non-African students who reported that they had access to these facilities were statistically significantly different in six of the eight facilities (Table 5.10). A smaller proportion of African students had access to a careers guidance teacher, laboratories, career information via a notice board or library and a regular display of students' science projects (Table 5.10). The disparity in access was particularly evident with respect to a computer laboratory, where 25% of African as opposed to 61% of non-African students reported to have had access to one. Even though there are differences in the proportion of African and non-African students who reported access to a notice board for interesting science material and the presence of an active school science club, these proportions are not statistically significantly different (Table 5.10).

The above results provide an overview of access by students to specific school facilities. For a more fined grained analysis, the access that students have to more than one facility was investigated. For this purpose, three distinct clusters of students were determined. Students who indicated that between 0 and 2 of the listed facilities were available at their schools were considered to come from low resource schools. Students from medium resource schools were those who indicated that between 3 and 5 of the listed facilities were available at their schools. Students who indicated that between 6 and 8 of the listed facilities were available at their schools were considered to come from high-resource schools. Using a chi-square test, a statistically significant association was determined for the relationship between levels of resourcing and race (Pearson chi-square = 24.6, d.f. = 2, $p < 0.001$). Consistent with the findings of the analysis of individual school facilities, the number of students who come from low resourced schools is higher for African (51%) than for non-African students (27%) (Table 5.11). Furthermore, the number of African students at medium and high-resourced schools is also lower than their non-African counterparts (Table 5.11).

Table 5.11. Distribution of students in low, medium and high resource schools by race

	Non-African		**African**			
	Freq.	**%**	**Freq.**	**%**	**Total**	%
Low resourcing	73	27	72	51	145	36
Medium resourcing	121	45	50	36	171	42
High resourcing	73	27	19	14	92	23
Total	267	65	141	35	408	100

Non-curriculum school science activities/events

Students were asked, in question 17 of the questionnaire (Appendix, pg. 90) to report on the occurrence of a variety of non-curriculum science-related events which occurred at their school, or which were arranged for them by the school. Table 5.12 provides a summary, in rank order, of events. The most common science-related activity that the school arranged for students was for them to visit a careers open day at a tertiary institution (Table 5.12). However, this was reported by only 6 out of 10 students. For all other activities, four (or fewer) out of 10 students reported that these occurred at their school. Particularly low was the proportion of students (1 out of 6) who reported that they had joined a school science club (Table 5.12).

Table 5.12 Rank order of the number of students who reported on the occurrence of specific non-curriculum science related events at their school

Activity	Frequency	Percent
School arranged for me to visit a careers open day at a university or technikon	280	62
School arranged for me to visited a science dept at a university or technikon	182	40
I entered a project in a school science competition	169	38
An engineer visited my school to talk about the work that s/he does	156	35
A scientist visited my school to talk about the work that s/he does	128	28
School arranged a science open day for students and parents to see our science projects	117	26
School arranged for me to visit an engineering company to see what they do	102	23
I joined a school science club	67	15

When race is taken into consideration, two prominent features emerge. First, for five of the eight activities enquired about, there is no statistically significant difference in the proportion of African and non-African students who reported that these events occurred at their school (Table 5.13). Secondly, statistically significant differences

Table 5.13. Comparison of the occurrence of specific non-curriculum science related events at the schools of African and non-African students

Facility	Non-African		African		Chi-square	Sig.
	Freq.	%	Freq.	%		
School arranged for me to visit a careers open day at a university or technikon	183	69	79	56	6.3	*
School arranged for me to visited a science dept at a university or technikon	115	43	53	38	1.1	NS
I entered a project in a school science competition	100	38	56	40	0.2	NS
An engineer visited my school to talk about the work that s/he does	99	37	44	31	1.5	NS
A scientist visited my school to talk about the work that s/he does	91	34	25	18	12.1	***
School arranged a science open day for students and parents to see our science projects	81	30	21	15	11.7	***
School arranged for me to visit an engineering company to see what they do	56	21	36	25	1.1	NS
I joined a school science club	39	15	26	18	1.0	NS

NS $p > 0.05$
* $p < 0.05$
*** $p < 0.001$

were found in the proportion of African and non-African students for whom a visit to a careers open day at a tertiary institution was arranged, at whose school a scientist visited to talk about the work that they do and, for whom the school arranged a science open day for students and parents to see the students science projects (Table 5.13). In the case of each of these last three items, a significantly lower proportion of African than non-African students reported that they were exposed to these events (one-sided Fishers Exact Test, d.f. = 1) (Table 5.13).

Science classroom activities

The nature of science classroom activities was investigated in question 19 of the questionnaire (Appendix, pg. 91). Students were asked to respond on the occurrence of a variety of activities which describe what might have happened in their school science classroom. Table 5.14 provides a summary, in rank order, of the occurrence of these activities.

Table 5.14. Rank order of the occurrence of specific activities in students' school science classrooms

Activity	**Frequency**	**Percent**
Our teacher demonstrated experiments while students watched	333	74
The class always wrote a test after each section of the syllabus had been completed	324	72
Our teacher often explained how science relates to everyday life	297	66
Our teacher always stressed the importance of working in a systematic way	241	54
Our teacher always stressed the facts of science	217	48
Our teacher allowed students to go beyond the regular laboratory exercises and do some experimenting of their own.	141	31
The class often discussed career opportunities in science and engineering in class	90	20
Our teacher had no time to demonstrate experiments	26	6

Overall, the activities that students most frequently reported as best describing what usually happened in their school science lessons reflect a very conventional teaching approach, as between 5 and 7 out of 10 students reported that the facts of science, the importance of working in a systematic way and regular classroom tests where important features of their school science experience (Table 5.14). With respect to how experiments were taught students' describe a teacher-centered approach to experiments with 7 out of 10 students reporting that they watched while their teacher demonstrated experiments—only 3 out of every 10 students reported that the teacher allowed them to go beyond regular laboratory exercises and to do some experimenting on their own. While three out of five students reported that their teacher often explained how science relates to everyday life, this does not appear to have been linked to discussions of career opportunities in science and engineering as only one out of five reported that such discussions were often held in class (Table 5.14).

When race is taken into consideration, no statistically significant differences were found in the proportion of African and non-African students who reported affirmatively on seven of the eight science-lesson activities students were asked to report on (Table 5.15). The only exception was the proportion of students who reported that career opportunities in science and engineering were often discussed in class, where a significantly higher proportion of African than non-African students reported that they did this (one-sided Fishers Exact Test, d.f. = 1) (Table 5.15).

Table 5.15. Comparison of the number of African and non-African students who said that these specific activities occurred in their school science lessons

Activity	**Non-African**		**African**		**Chi-square**	**Sig.**
	Freq.	**%**	**Freq.**	**%**		
Our teacher demonstrated experiments while students watched	204	76	98	69	2.3	NS
The class always wrote a test after each section of the syllabus had been completed	195	73	104	74	0.1	NS
Our teacher often explained how science relates to everyday life	175	65	94	67	0.1	NS
Our teacher always stressed the importance of working in a systematic way	153	53	69	49	2.6	NS
Our teacher always stressed the facts of science	135	51	66	47	0.5	NS
Our teacher allowed students to go beyond the regular laboratory exercises and do some experimenting of their own.	85	32	45	32	0.0	NS
The class often discussed career opportunities in science and engineering in class	46	17	38	27	5.3	*
Our teacher had no time to demonstrate experiments	12	5	12	9	2.7	NS

NS $p > 0.05$
* $p < 0.05$

Students' preferred science classroom activities

In question 20 of the questionnaire (Appendix, pg. 91), students were asked to indicate their preferences with regard to the nature of their science classroom activities. Activities identified in Section C of Woolnough's (1994) questionnaire were instrumental in drawing up this list of activities. Figure 5.1 provides a summary of how students responded to each item. Overall, the majority of students reflect an enthusiasm for learning to do science through scientific experiments (item 20i) with 6 out of 10 students agreeing that observing laboratory experiments systematically, and writing up results correctly, helped them to understand the logic of science (20d).

At the same time, however, students' views mirror a rather conventional approach to school science experiments with 7 out of 10 students reporting that they preferred it when their teacher gave clear instructions to follow when doing laboratory experiments (20b). Not surprisingly, therefore, students appear to be uncertain about their own ability to perform experiments; 2 out of 10 students disagreed that they felt happiest when "my teacher allowed me to plan my own laboratory experiments in class", while 4 out of 10 were not sure how they felt about this (20h).

Overall, students reflected a preference for a more teacher-directed approach to classroom activities; as they felt happiest when activities and notes were prepared for them by their teacher (items 20c and 20e). At the same time, however, students seem to value an interactive classroom environment, as 4 out of 10 students reported that they liked to solve scientific problems with friends (20f), and 7 out of 10 students reported that they felt happiest when their suggestions, ideas and discussions became part of the lesson (20g) (Figures 5.1a-b).

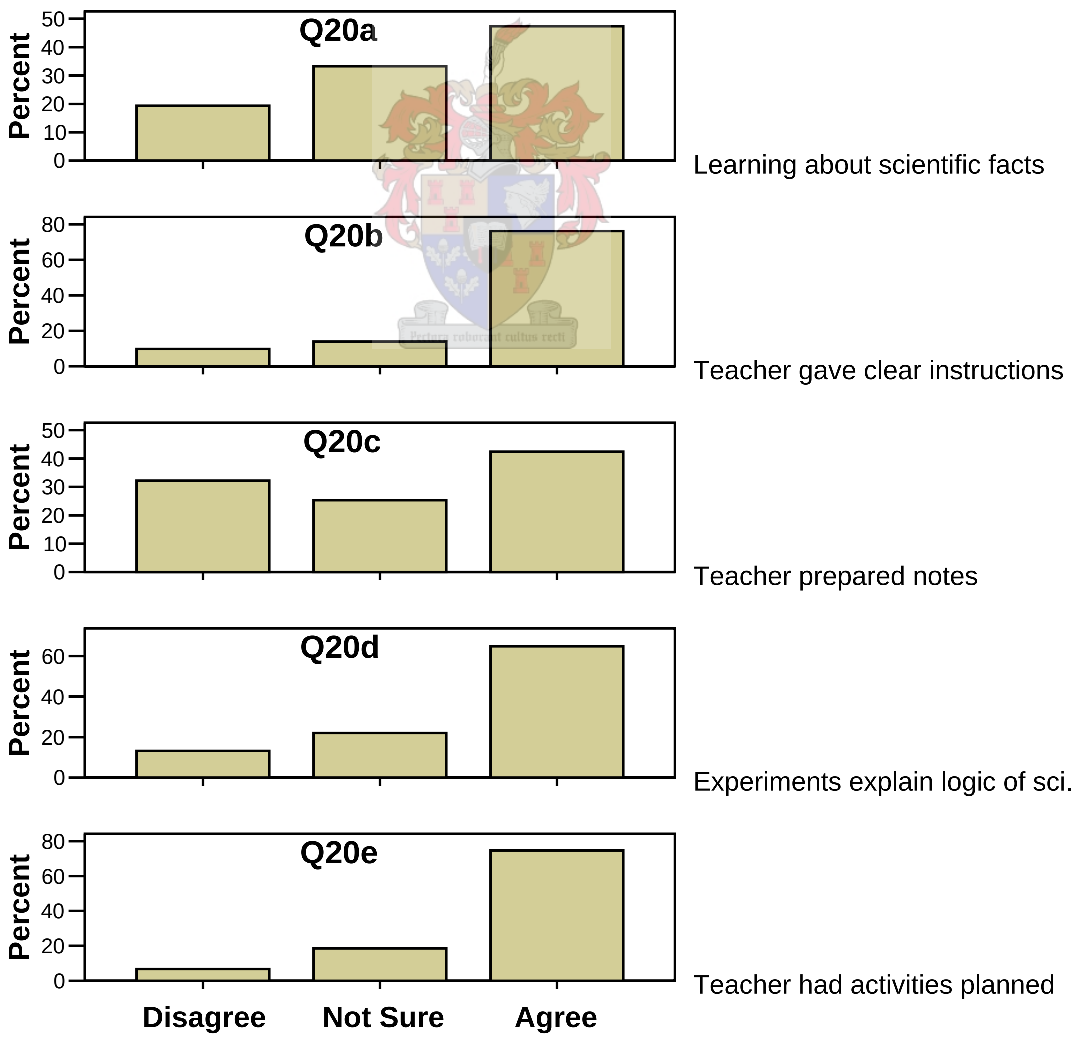

Figure 5.1a. Students' perceptions of particular aspects of their school science classroom experiences (Q20a-e in the Appendix).

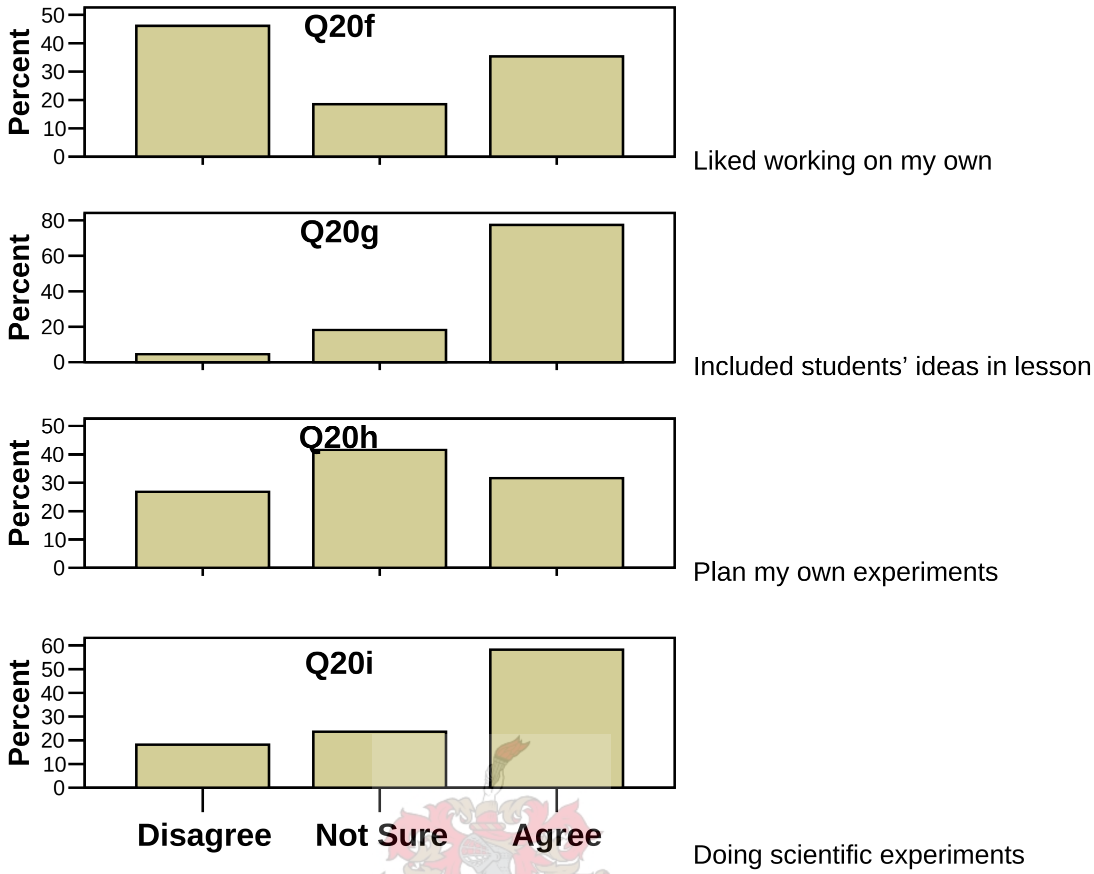

Figure 5.1b. Students' perceptions of particular aspects of their school science classroom experiences (Q20f-i in the Appendix).

I also undertook an analysis of students' preferred classroom activities by faculty, race and sex. An overall chi-square test of independence was performed on a 3 x 2 contingency table of the response categories and the two categories within the three variables of interest, in order to establish whether the frequencies within the various responses to items in question 20 deviate from a common ratio. Statistically significant differences were found only in item 20(b) (Pearson chi-square 6.733, d.f= 2, $p = 0.035$) in the analysis by faculty, in items 20(b) (Pearson chi-square 13,675, d.f. = 2, $p = 0.001$), 20(d) (Pearson chi-square 16.367, d.f. = 2, $p = 0.000$) and 20(f) (Pearson chi-square 6.759, d.f. = 2, $p = 0.034$) in the analysis by sex; and in items 20(a) (Pearson chi-square 15.848, d.f. = 2, $p = 0.000$) and 20(c) (Pearson chi-square 11.638, d.f. = 2, $p = 0.003$) in the analysis by race.

A significant chi-square value indicated that the categories forming the table were not independent, that is that the proportion of students who responded to any one of the three responses was associated with one of the two categories for each of the three variables of interest (i.e., faculty, sex and race). Further analyses were then performed in order to isolate sources of association within the tables to "identify sub-tables that break up the chi-square statistic into more interpretable pieces, enabling those categories (of responses) responsible for a significant overall chi-square value to be identified" (Everitt, 1992:41). Methods recommended by Everitt (1992) for partitioning the 3 x 2 contingency table into independent and non-independent 2 x 2 tables were used. In cases where specific hypotheses about particular 2 x 2 tables were to be tested, the one-sided Fisher's Exact Test with one degree of freedom (Everitt, 1992) was employed.

With respect to faculty, a statistically significantly higher proportion of engineering (13%) than science students (6%) disagreed that they felt happiest when their teacher gave clear instructions to follow when doing laboratory experiments (Fishers Exact Test, one-sided, $p < 0.01$).

A similar sentiment was expressed by female students with a statistically significantly higher proportion of female (87%) than male students (71%) reporting that they were happiest when their teacher gave clear instructions to follow when doing laboratory experiments (Fishers Exact Test, one-sided, $p < 0.001$). Observing laboratory experiments systematically and writing up results correctly was also favoured by female students. A statistically significantly higher proportion of females (78%) than males (58%) reported that this technique helped them to understand the logic of science (Fishers Exact Test, one-sided, $p < 0.001$). A difference between females and males was also evident with respect to students working in groups. A statistically significantly higher proportion of females (54%) than males (43%) disagreed that they liked to solve scientific problems on their own rather than with friends (Fishers Exact Test, one-sided, $p < 0.05$).

With respect to race, the enthusiasm for learning to do science through scientific experiments (that was evident in the analysis of the overall sample (Figure 5.1, pg. 56-57) was not reiterated. A statistically significantly higher proportion of African students (53%) than non-African students (43%) reported that they found learning about scientific facts to be the most exciting aspect of school science (Fishers Exact Test, one-sided, $p < 0.05$). The only other contrast found in the analysis by race was that a statistically significantly higher proportion of non-African students (47%) than African students (34%) indicated that they felt happiest when their teacher had lots of notes prepared for them (Fishers Exact Test, one-sided, $p < 0.01$).

Factors which students say influenced their decision to study science and engineering

In question 22 of the questionnaire (Appendix, pg. 92), students were asked to consider a list of possible factors that may have influenced their decision to study science and engineering. Factors identified in Section C of Woolnough's (1994) questionnaire were instrumental in drawing up this list of factors. For each factor, students were asked to indicate whether they believe that this had an encouraging (positive) or discouraging (negative) influence on the decision that they had made. Students were also given the opportunity to indicate if they were not sure or if this did not apply to them. Figure 5.2 provides a visual overview of how students responded to each of the three categories of responses per item.

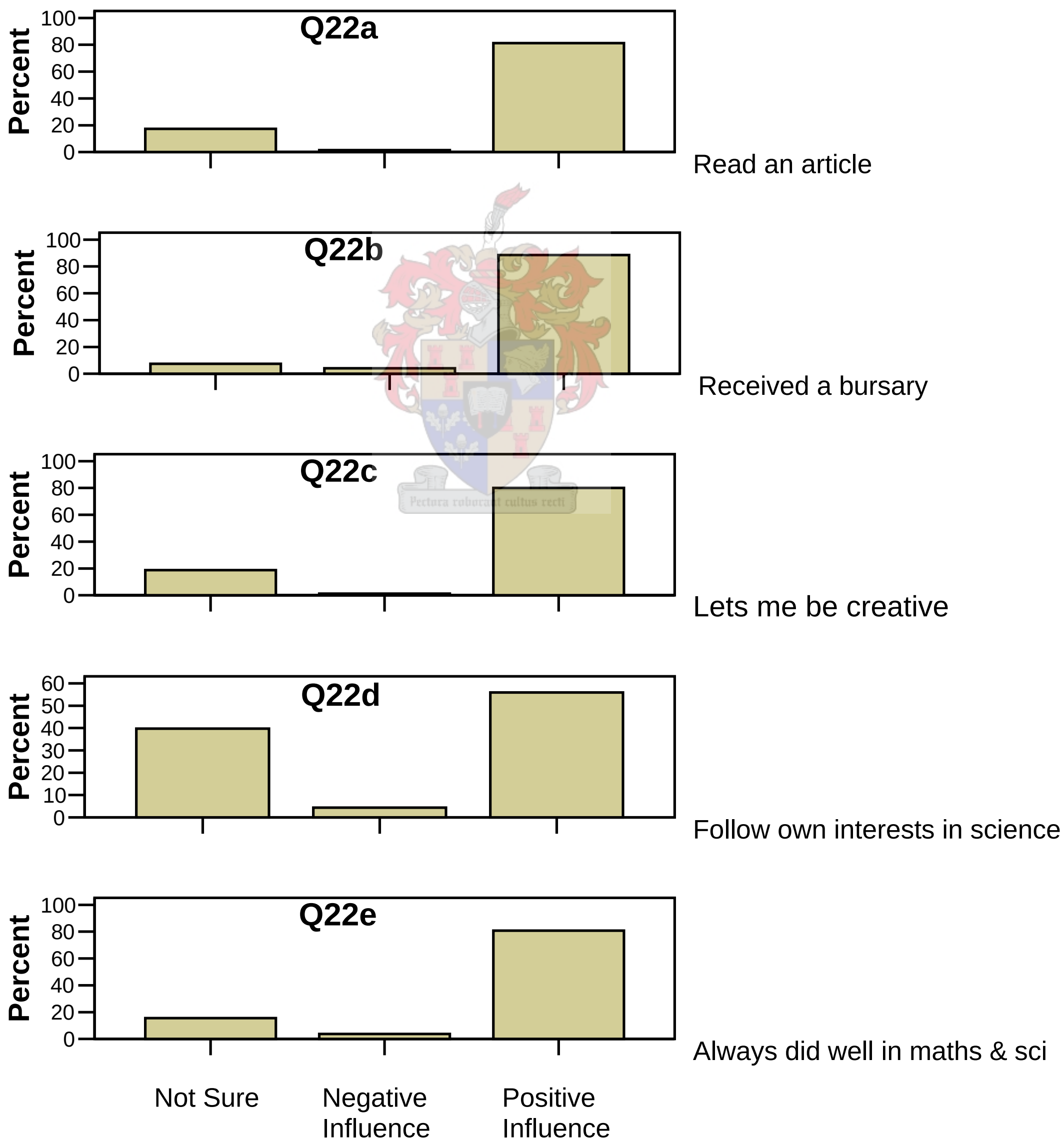

Figure 5.2a. Students' responses to individual factors of influence (Q22a-e in the Appendix).

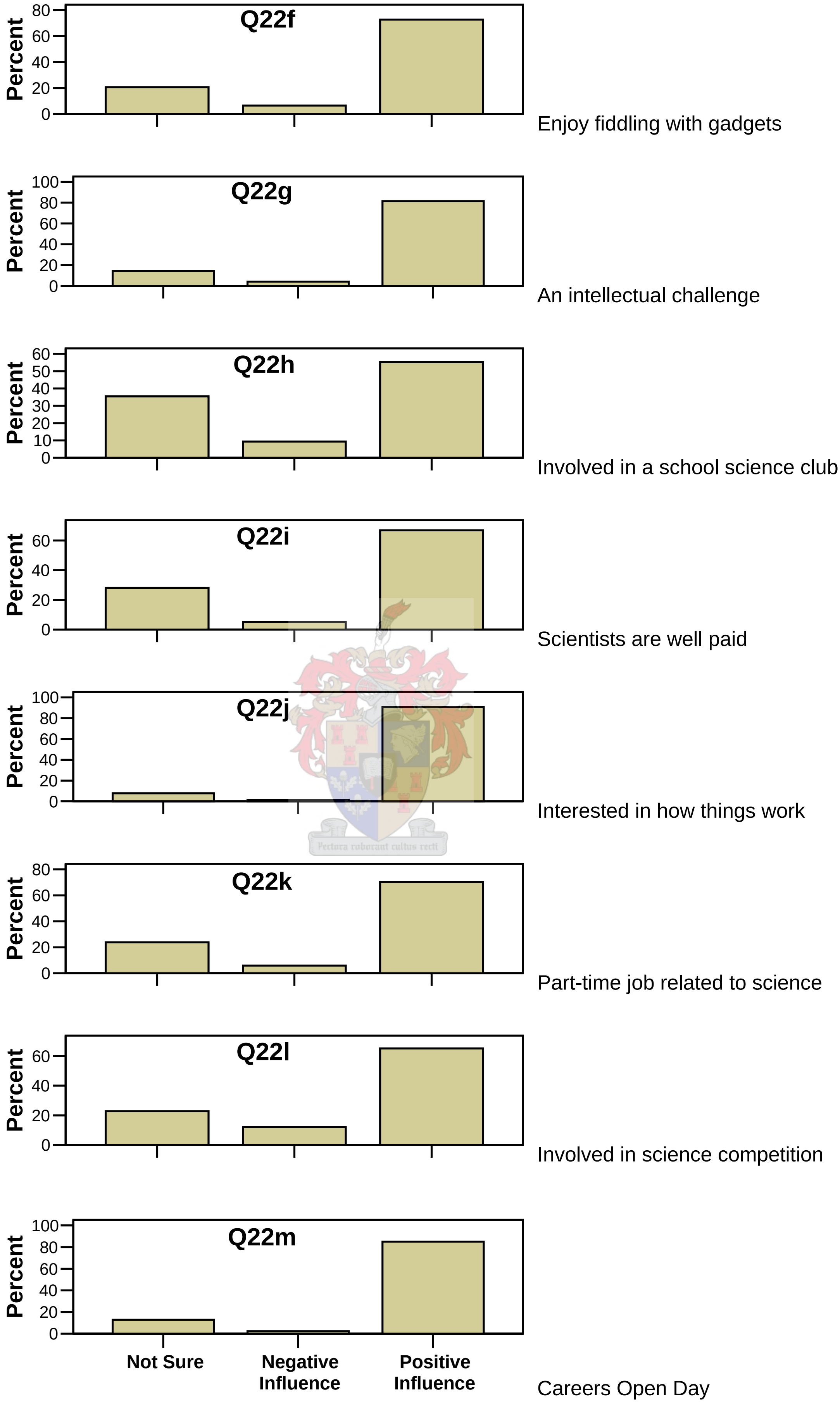

Figure 5.2b. Students' responses to individual factors of influence (Q22f-m in the Appendix).

The factors that students were asked to respond to are thought to be key influences in motivating students towards science and engineering degrees (Woolnough, 1994). Not surprisingly, students' responses overall reflect that the majority of factors had encouraged them to pursue further study in science or engineering. Also, the sample used in this study is homogenous in the sense that the students who participated in this study have <u>all</u> actually made the decision to study science and engineering. Hence a low number of "negative influences" should have been anticipated here. Administering the questionnaire to "successful" students is acknowledged elsewhere as a limitation of the study (pg. 68).

Nevertheless, for a surprisingly high number of factors, students indicated that they were not sure of the effect that this specific factor had on their decision to study science or engineering. However, it is worth noting that as the percentage of those who indicate a positive influence decreases, there is a corresponding increase in the percentage of those who indicate that they are not sure. This suggests that a low percentage of positive influences do not indicate a high percentage of negative influence but rather a higher percentage of those who are undecided about the influence that a specific factor had on their decision.

Three broad trends emerged from the analysis of the factors that students say influenced their decision to study science or engineering. Firstly, personal motivation appears to be influential in the decisions that students make. Responses indicated that students were encouraged to do science or engineering because they were interested in knowing how things work (91%) (22j), that they consider doing science to be an intellectual challenge (81%) (22g), that they want to be creative, to build and design things (80%) (22c), that they enjoy making things and fiddling with gadgets (73%) (22f) and that they always did well in mathematics and science while at school (81%) (22e). Sixty-seven percent of students who thought that scientists and engineers have well paid jobs (22i) reported that this positively influenced their decision to study science or engineering (Figure 5.2). Secondly, receiving a bursary to study science or engineering (22b) was also high-ranking—89% of bursary recipients reported that this encouraged them to pursue a career in science or engineering (Figure 5.2). Lastly, access to information also seems to influence the decisions students make. Eighty-five percent of respondents who indicated that they received information at a Careers Open Day (22m) said that this had encouraged them to study science or engineering. Similarly, reading an article about a career in science or engineering (22a) encouraged 81% of students who did so, to pursue this option (Figure 5.2).

Earlier it was shown that there is a poor culture of participation in extra-curricula activities (such as a school science competition or science club) in schools (question 17, pg. 90). Not surprisingly, when responding to this question, a high number of students reported that these factors did not apply to them. However, of those who indicated that they had participated in a school science competition or science club, 65% and 55%, respectively, reported that this had encouraged them to study science or engineering. Of those who reported that they could follow their own interests at school, only 56% believed that this had a positive influence on the career choice that they have made.

A similar analysis by faculty, race and sex was also performed by determining the rank of these influences for engineering and science, African and non-African and male and female students, respectively. Overall, these analyses show that the broad trends identified for the overall sample above, apply also to the various subgroups. In general, factors related to personal motivation appear to have the most positive influence on students' decision to pursue further study in science or engineering, followed by—in rank order—access to information, receiving a bursary, and participation in extra-curricula activities. Interestingly, the trends described above for the overall sample, apply also to engineering, male and non-African students. That is, for each of these three subgroups, the factors that students rank in their list of top eight factors are identical as those for the overall sample. Within the subgroups, however, some interesting differences emerge. These are discussed in the section below.

While an interest in knowing how things work was the top ranking factor of influence for engineers (94%), information received at a careers open day about a career in science and engineering was the factor for which the highest percentage of science students (90%) reported a positive influence. Also notable, is the difference in how students value participating in a school science competition. Science students rank this factor within the top eight factors of influence, with 69% of those who indicated that this applied to them reporting that it had a positive influence on their career choice. Engineering students do not rank this in their top eight factors of influence, with 62% of respondents reporting that it had positively influenced their choice. The personal motivation that engineering students derive from "creating, building and designing things” and from “making and fiddling with gadgets”, is also not shared to the same extent by science students. While 88% of engineering students who said science allows them to be creative, reported that this encouraged them to study engineering, only 69% of the science respondents reported this. Similarly, of those who responded to “I enjoy making things and fiddling with gadgets”, a higher proportion of engineering students (78%), than science students (65%), reported that this had a positive influence on their decision.

The factor for which the highest percentage of African students reported a positive influence was information received at a careers open day about a career in science and engineering (93%). For non-African students, the corresponding figure is 83%, with their top-ranking factors being receiving a bursary to study science or engineering (91%) and an interest in knowing how things work (91%). Participating in a school science competition was also viewed differently by the two subgroups. African students, rank this factor within the top eight factors of influence, with 82% of those who indicated that this applied to them, reporting that it had a positive influence on their career choice. Non-African students do not rank this in their top eight factors of influence, with only 59% of respondents reporting that they were positively influenced by this factor. Also not in the list of top eight influencing factors of African students is “I enjoy making things and fiddling with gadgets”. Only 59% of African respondents reported that this had a positive influence on their decision, as opposed to 82% of non-African respondents.

Overall, males and females reacted in a similar way, except in the case of two factors, both of which are at the lower end of their ranking of influencing factors. Of those who indicated that they had participated in a school science competition, a higher proportion of females (70%), than males (62%), reported that this had a positive influence on their decision. One the other hand, more males (75%) than females (67%) report that the enjoyment that they derive from making things and fiddling with gadgets positively motivated them to study science or engineering.

Summary

The sample of science and engineering students who participated in this study were predominantly male. In addition to being smaller in number, the majority of female respondents in the sample were registered in the science faculty. Students aspired to classic career profiles that one would associate with the degree choices that they have made. Of extreme concern, however, is the low number of students who indicated that they expect to go on to teaching. Parents, career counselors and teachers most influenced students' decision to study science or engineering, even though a very small number of respondents have a parent working in a science-related environment. Less than ten percent of the sample had a part-time or holiday job in a science-related environment.

Eighty-seven percent of students studied Physical Science at school—the only science subject for 12% of engineering students. Overall, students displayed a very positive attitude towards science which was also reflected in the reasons why they chose to study a science subject at school. Not surprisingly, African students had a very different experience with respect to school facilities, with the majority reporting being part of a large class and coming from low-resourced schools. With respect to non-curriculum school science activities and events, student's responses generally reflected a poor commitment on the part of schools to expose students to non-curriculum activities generally thought to promote a general interest in science. With respect to the nature of science classroom activities, students described a conventional teaching approach. Students also reported a very teacher-centered approach to experiments which was more favoured by science than by engineering students, by African than by non-African students, and by female than by male students. Overall more males than females showed a preference for working in groups and solving problems with their friends.

Personal motivation, receiving a bursary and access to information were the main factors that students said influenced their decision to study science or engineering. Some differences emerged between the various subgroups. While information received at a careers open day and participating in a school science competitions was crucial for science students, engineering students showed a general curiosity for science and knowing how things work, creating and designing things and fiddling with gadgets. For an overwhelming number of African students, information received at a careers open day was important, while a curiosity for science and receiving a bursary were equally important in influencing non-African students to pursue further study in science or engineering.

The results presented above demonstrate that the decisions that students make are influenced by a variety of factors much of which is not the stuff of educational curriculum reform. In the following chapter, these results are discussed and an argument made for the development of strategies that use multiple influences to popularize science in schools and in this way, hopefully motivate learners positively towards science and later, careers in science.

Chapter Six

DISCUSSION

Introduction

In this study, it is argued that scientific and technological innovation presents a challenge to citizens worldwide and, in particular, to their ability to adapt to the concomitant changes that this brings to their socio-economic life. Internationally, politicians, educators, business people and parents now examine the quality of science education in schools along a continuum ranging from interest to concern, depending on the ability of citizens to acclimatize to a world fast being transformed by scientific and technological innovation. Based on the results of their recent study on mathematics and science education in South African schools, the Centre for Development Enterprise (CDE) concluded that a national crisis has developed and that "the maths and science education system is failing to deliver enough school-leavers equipped with HG maths and science to meet the country's need" (2004:5). Obstacles which they suggest need to be overcome include increasing the number of students who enroll for and pass higher grade Physical Science and Mathematics in Grades 10-12, thereby allowing them to enroll for higher education courses (CDE, 2004).

These sentiments reflect the context within which this study was conducted. However, it was argued earlier (Chapter 1, pg. 6) that without an interest in science, citizens are unlikely to be inspired to be scientifically and technologically innovative; unlikely to contribute to the debate on how science and technology should be applied in addressing developmental issues; unlikely to be concerned with the pressures that development may place on the environment; and unlikely to be able to make sound decisions in their personal lives with respect to science-related matters. Furthermore, without such an interest, it is unlikely that learners will be motivated to pursue scientific or technological study and/or careers after school.

It was envisaged that the information sought in this study would illuminate the in-and-out-of school resources available to schools and educators to promote a positive attitude toward science amongst learners. The following research questions were thus addressed: 1) What does the background profile of students who have decided study science or engineering at UCT look like?, 2) What are the characteristic features of their school-science experience with reference to school facilities, non-curriculum science-related activities and the nature of science classroom activities?, and 3) What are the factors that students' think most influenced their decision to pursue a career in science and engineering?

This study was formulated as having a descriptive purpose and hence a survey research design was used. Self-reported retrospective data were collected using a questionnaire administered to first-year science and engineering students (N=451). In this chapter, the results presented in the previous chapter are discussed with reference to the three research questions that were asked.

Limitations of the study

This study is concerned with the factors that motivate students positively towards further study in science or engineering and later science-based careers. The educational indicator of success is the student who has actually gone on to register for a science/engineering degree. Consequently, individual science and engineering students were selected as the unit of analysis. This, I think, represents a limitation of the study. If these are all "successful" students then the likelihood that they were positively influenced by the factors tested is high. Consequently, I have no measure of, and nothing against which to measure, discouraging factors. It must therefore be acknowledged that this study is an examination of the degree to which "encouraging" factors have actually influenced students' decision to study science and engineering.

Background profile of students

English is the home language of majority of students who participated in this study (55%). Thirty-two percent of students speak one of the nine official African languages. The number of African language speakers who participated in this study (in 1999) must be seen within the context of change in the student composition at UCT. Cooper and Subotzky (2001) report that between 1988 and 1998 the student composition at UCT underwent a major transformation. They report that the number of African students enrolled at UCT increased from 900 in 1988 to 4296 ten years later, representing 27% of the total student enrolment in that year. This increase is also relevant in the context of Kahn's (2006) assertion that South Africa now has a sufficient number of African candidates who qualify for access to all first-year engineering course.

But who are the individuals who are doing science? This was the focal point of the first question posed in this study. The sample of students who participated in this study is predominantly male. Given that a pass in higher grade matric Mathematics is a pre-requisite for admission to science and engineering, it could be argued that the male bias that we see here reflects the historical trend in South Africa that more boys than girls enroll for Mathematics in Grades 10-12 (Arnott, Kubeka, Rice & Hall, 1997). Furthermore, based on his analysis of matric Mathematics results in recent years, Kahn (2001) argues that more boys are likely to pass than girls. This implies that until such time that these trends change, the male bias that we see in enrolment for science and engineering degrees is unlikely to change.

Also interesting in the gender distribution within this sample is that in addition to being small in number, the majority of female students have chosen to register in the science faculty. It is cautiously suggested here that this might imply that females to do not see engineering as an attractive career option. Or, this trend might be explained by the fact that a science degree offers a greater variety of career options. However, it might also be that females have different attitudes toward the role of science in society and that these attitudes are reflected in the career choices that they make. Such views are however speculative and further in-depth investigations into why females veer towards careers in science as opposed to engineering, are required.

Eighty-six percent of students sampled studied Physical Science in their matric year. The two most common science subject combinations were Biology and Physical Science, and Biology, Physical Science and Geography. Twelve percent of engineering students chose Physical Science as the <u>only</u> science subject in their matric year, as opposed to 4% of science students. The salient point that I think these findings make is that Physical Science is the common element in the background of the majority of students who have chosen to study science and engineering. If, therefore, we accept that an interest in science is important in motivating students towards further study in science and engineering (Robertson, 2000; Woolnough, 1994; Woolnough et al., 1997), then it seems that, at the level of the school curriculum, Physical Science is an appealing science subject choice. This finding, I believe, provide a justification for actively promoting Physical Science in school. This may involve more individual support and attention, an appealing and meaningful way of teaching Physical Science, substantial rewards in the form of scholarships and loan forgiveness for those who want to teach Physical Science. For example, Williams (1990) makes a case for science specialists to be used in elementary schools in the USA. He argues that while it is not reasonable to expect teachers to maintain an awareness of all the science in the news and its relevance to learners, a specialist could do so and thereby help in creating a general enthusiasm for science in schools (1990:32).

When we relate students' science subject combinations to the reasons why they chose to study at least one science subject in matric, the primary reasons in rank order were that they a) knew that they needed a science subject to have a career in science or engineering b) liked General Science in standards 6 and 7 (i.e., Grades 8 and 9) and wanted to know more about science, and c) thought that they might need a science subject to get into university one day (Table 5.6, pg. 48). These findings are consistent with Woolnough's (1994) sentiments, namely, that some students simply love the science subject and it is this passion that takes them on to higher education—as in the case of those who indicated that they liked science and wanted to know more about it. Others, we could argue, have a sense of their future careers from quite an early age and realize that science might be important for gaining entry into higher education. Their ambitions then become cemented at some stage in their school career. This implies that some students have a 'dream picture' of what they might like to do and this drives the decisions that they make about subject choices. This being the case, it is likely that by providing students quite early on in their schooling with examples of what scientists do, with details of what the entry requirements for specific programs at HE level are, and so forth, that students will be better equipped to manage the science subject choices that they make. Indeed, for some students it might be more sensible to focus on <u>one</u> science subject only and not to put themselves under strain by trying to cope with a subject that they "think they might need to get into university one day". Results presented in the previous chapter suggest that schools seriously under-utilize resources such as a careers library, a noticeboard for relevant career and study information, and arranging visits to universities and industry, all of which could help to give students a more exact idea of which science subject they might need to keep future study and career options open.

The second observation that I wish to make regarding the reasons that students give for studying a science subject at school relate to the issue of high-school tracking (e.g., Oakes & Guiton, 1995). Less than 10% of respondents indicated that their school decided which subjects they should do or that they had no choice regarding the science subjects that they studied at school. This result suggests that for the sample used in this study, the kind of tracking influences that Oakes and Guiton (1995) describe (see Chapter 3, pg. 26) did not apply. Obviously, this does not imply that tracking mechanisms do not exist. On the contrary, the recent CDE study found that because South African schools were under such enormous pressure to produce "good" matric results, many students who could have passed mathematics or science subjects on the higher grade were encouraged by the school to rather do these subjects on the standard grade (CDE, 2004). This suggests that further investigation is required into tracking mechanisms used in schools and how these impact on the number of students who finally pass these subjects in matric. With the implementation of FET curriculum, issues of Standard Grade are no longer pertinent. Rather the issue is that students should be encouraged to take Mathematics as opposed to Mathematics literacy.

Nevertheless, the career aspirations that students have raise some interesting questions. The science and engineering students who participated in this study were treated as homogeneous groups, that is, no distinction was made between students in the various engineering disciplines nor between students with differing science majors. Consequently, the assumption was made that engineering students expect to work as an engineer in the future. Science students, in contrast, are usually not associated with a fixed career profile which points to the diversity of the sciences in general. This being the case, the career aspirations of the science student sample was of some interest. Eighty percent of the science students in the sample expect, in the future, to be working as a scientist, a computer scientist, a medical doctor or an engineer. With hindsight, it is acknowledged as a limitation of this study that it is not clear what exactly students mean when they say they want to be a scientist. It is assumed that students mean that they expect to be working in a field related to their area of specialization. Robertson (2000) also reported this lack of clarity from students who reported that they would consider working as a scientist. When asked to clarify, a third of Robertson's (2000) respondents indicated that their career choice was "research of some kind" (Robertson, 2000:1214). What this suggests, therefore, is that it is uncertain whether students in this study would in fact have been able to provide specific details on their career plans at the time of completing the questionnaire. Nevertheless, this raises an interesting element regarding the time that students actually make career decisions. Woolnough (1994) reported that many of the students who continue with physics and chemistry into higher education do so for the love of the subject and not for career reasons, but that the majority was undecided about their actual career plans at the time of completing school. By contrast, of those who wanted to be engineers, 70% had made this decision by the time they had completed school (1994:664).

On the one hand, one could argue that from the time a student says “I want to be an engineer or a medical doctor”, it becomes easier for students, parents and schools to focus on specific influences that feed this aspiration. This may be in the form of inviting guest speakers to speak at school, undertaking a relevant school science project, doing part-time/holiday work at mom’s or an uncle’s firm, or building a robot with a friend. However, many students do <u>not</u> have a definite career choice by the time they leave school, as Woolnough (1994) demonstrated. In this case, registering for a degree in science does offer the student the flexibility to feed his/her interest for science, while at the same time keeping his/her options open to find a particular niche as they go along. Here again, exposing students to a variety of science-related career options, displaying career information on notice boards, or making it possible for students to attend a careers open day, must be utilized as useful ways of stimulating their general interest in, and enthusiasm for, science.

Of extreme concern, however, is the low number of students who indicate that they wish to go on to become a science teacher—only 1% of science students indicated this (Table 5.2, pg. 45). This result has implications in the context of this study. Results of previous studies show that teachers play a significant role in inspiring students’ interest in science (George & Kaplan, 1998; Woolnough, 1994; Woolnough et al., 1997). Furthermore, if, as the CDE (2004) recommends, South Africa urgently needs to increase its Grade 10-12 higher grade mathematics and science enrolment, then we need more science and mathematics teachers (Kahn, 2006). Ideally, therefore, we want to see vast numbers of graduates exit higher education institutions with a teaching qualification in mathematics and science. There are two things we could say about the shockingly low number who reported here that they wish to become a science teacher. The first is that it demonstrates the enormity of the challenge that South Africa faces to expand its pool of well-qualified teaching specialists. If the number of students who enter HE with the intention of entering the teaching profession is so small, then it is reasonable to assume that we are unlikely to see a high number of teachers who exit HE with a teaching qualification. The second comment is perhaps more positive. The CDE (2004) argues that the “first emphasis in developing educators must be on content knowledge, followed by teaching skills” (2004:32). If we rely on the fact that some science students are uncertain about their final career choice at the beginning of their academic careers, then the acquisition of teaching skills, as a desirable post-graduate option, must be actively promoted amongst this group at some optimal point during their undergraduate years. But, the findings here suggest that teaching is not seen as an attractive career option. Why this is so, and how we correct it, in my view, requires urgent investigation.

It is my view that serious attention must be paid to the role that significant others play in influencing the decisions that students make. Overall, a parent, a career counselor and a teacher were the persons that more than half of the sample said most influenced their decision to study science or engineering (Table 5.3, pg. 46). Overall, these findings correspond with other findings that the home environment and what teachers do, has a substantial influence on students’ attitude and achievement (George & Kaplan, 1998; Robertson, 2000; Schibeci & Riley, 1986; Woolnough, 1994; Woolnough et al., 1997). This general trend applies also more to African than non-African students. When sex was taken into account, more females than males indicated that their mother was the person who most influenced their career choice, but for more males than females their father was influential (Chapter 5, pg. 45). More non-African than African students reported that their father was the person who most influenced their career choice. If we accept that parents play such an influential role, then it makes sense to recruit parents into general career marketing strategies. By this I mean that we would want parents to be informed about careers opportunities in science and technology. We would want parents to receive advertising, know where to find information, be aware of bursary opportunities, and so on. For example, HE education institutions send posters to schools advertising their programs. These are placed on noticeboards and rely on the fact that parents will enter the school premises and read them. Similarly, career information is sent directly to students or parents on request. Again, this relies on the fact that students know what information they require and to whom they must address enquiries. The findings of this study suggest that we need to examine how schools can be used to channel information directly to parents on a personal level and so into the home environment.

Interestingly, very few students in this sample have a parent with a science-related occupation; 12% of mothers and 24% of fathers. This, I believe, reflects a general lack of emphasis on scientific and technological careers in South Africa. Nevertheless, students who participated in this study report that they were sufficiently influenced by their parents' views to choose a career in science and technology. Although small in number, parents who have an occupation related to science or technology provide an obvious resource—within the school environment—which can be tapped into. Parents can share their work experiences with students or offer holiday-job opportunities in the workplace. The fact that less than 10% of students reported that they had a part-time/holiday job science-related job while at school, in my view, suggests that there is a need for such parent-school partnerships. Also, the findings suggest that parents, particularly mothers, can become important role models of people-in-science. The need for such role models is often highlighted, particularly by studies concerned with the low number of females who are attracted to science (Fort & Varney, 1989; Hammrich, 1997). It is suggested here that the school environment can provide a place where the role models become visible, where they become ordinary and where stereotypical images about what it is that scientists and engineers do, and who they are, are broken down.

Students' experience of science while at school

The second question that was posed in this study was what the characteristic features of students' school-science experience were with reference to school facilities, non-curriculum science-related activities and the nature of science classroom activities. The vast majority of students reported that they had a careers guidance teacher at school (79%). Yet, only 40% had access to career information either via a school notice board for careers information or a school careers information library. The question that this raises is how career guidance is managed at school. It is argued here that the findings with respect to students who reported that a careers counselor or teacher was the person who most influenced their career choice (Chapter 5, pg. 45) justifies the time and effort required to maintain the dissemination of interesting higher education and career information. Furthermore, a case is made here to co-opt parents and senior learners into sourcing information, updating noticeboards, circulating career advertising to parents and establishing a careers information library. Not only would this alleviate the burden on already over-worked staff but also promote a general culture of support for science within the school.

It is not surprising that when race was applied to the analysis of available facilities, the patterns that emerged (Table 5.10, pg. 51) reflect disparities that are generally attributed to the apartheid model of inequitable school funding (Kahn, 2001, 2004). In six of the eight facilities enquired about, a statistically significantly lower proportion of African compared to non-African students reported that they had access to these facilities (Table 5.11, pg. 52). What this means, is that African students have a very different school science experience than their non-African counterparts. In the case of some facilities, such as the provision of laboratories, strategies to address these inequities are tied to financial conditions being met, over which schools have little control. However, there is no reason why fewer African students should have access to a careers guidance teacher, career information via a notice board, a careers information library, a regular display of students' science projects, a notice board for interesting science material, and an active school science club (Table 5.10, pg. 51). Certainly, we could argue this reflects poor management/ organizational skills/ competencies on the part of schools. However, I believe that in each of these explanations lies an element of the generally poor culture of promoting and popularizing science that we see in developing countries (Jegede, 1997; Ogunniyi, 1988), and that this is what the current curriculum reforms will hopefully begin to change.

With respect to the non-curriculum school science activities that took place at school or that were arranged by schools, the salient feature that emerges is that there is a poor commitment on the part of schools to expose students to activities generally thought to promote an general interest in science. All students have equally poor exposure to, and experience of, the events enquired about (Tables 5.12 and 5.13, pg. 54). For six out of ten students the school arranged a visit to a careers open day at a tertiary institution. For all other activities, forty percent (and fewer) of students reported that these occurred at, or were arranged by, their school. A statistically lower proportion of African than non-African students reported that the school arranged for them to visit a careers open day, that a scientist visited their school, and that the school arranged a science open day where science projects were displayed. These results demonstrate that there is tremendous scope for increased utilization of these resources in **ALL** schools. Further investigation into how they become part of the school science culture is required.

With respect to the nature of science classroom activities, the majority of students reflected an enthusiasm for learning to do science through scientific experiments, albeit with preference for a teacher-driven approach to classroom activities. Overall, the nature of science classroom activity reflect a rather conventional approach to teaching science, where the facts of science, working in a systematic way and regular tests were important features of students' school science experience (Table 5.14, pg. 54). Similarly, students describe a teacher-centered approach to science experiments, where they generally watched while their teacher demonstrated experiments and were presented with little opportunity to do some experimenting of their own.

When race is taken into account, two interesting trends emerged with respect to the type of activities that took place in the classroom (Table 5.15, pg. 55). Firstly, in 7 of the 8 science-lesson activities enquired about, no statistically significant difference was found in the proportion of African and non-African students who reported on these items. This implies that overall there is no difference in the nature of the science classroom experience that students have. The only deviation is that a significantly higher proportion of African than non-African students reported that career opportunities in science and engineering were often discussed in class. This difference is of particular relevance to this study particularly when we consider that a higher number of African than non-African students reported that a teacher was the person who most influenced their career choice. In my view, this demonstrates the valuable role that teachers can play in exposing students to higher education and career possibilities in science. This finding is consistent with findings of other studies (George & Kaplan, 1998; Robertson, 2000, Woolnough et al., 1997). By implication then, teachers need to be well equipped to offer advice, provide information, and guide students as to where to find appropriate information, and so forth. In this regard, the science specialist that Williams (1990) advocates presents a tantalizing option as a possible strategy for schools.

With respect to the activities that students' prefer, a statistically significantly higher proportion of African than non-African students reported that they found learning about scientific facts to be the most exciting aspect of science. How this relates to what generally happens in their science classrooms (i.e., to the nature of their science lessons) needs further investigation. Overall, students are enthusiastic about doing scientific experiments, but their preferences in this regard mirror the conventional approach to teaching that they have been exposed to—they felt happiest when notes were prepared for them by their teacher, they prefer it when they are given clear instructions to follow when doing experiments, and they agreed that observing experiments systematically and writing up results correctly helped them to understand the logic of science. Female students in particular demonstrated a preference for the latter two, more teacher-centered, approaches to teaching. Male and engineering students on the other hand were more inclined towards a less structured teaching approach. This is consistent with the findings in the Woolnough (1994), Woolnough et al. (1997), and Robertson (2000) studies and implies that strategies are required to find innovative ways of teaching—one that exploits childrens' natural curiosity for tangible things. Of particular significance to this study is that student's responses reflect a distinct uncertainty about their own ability to perform experiments. This, in my view, is explained by the structured teaching environment that students experience which does not encourage them to feed their curiosity to probe into problems beyond what is presented in the curriculum. This, I believe, provides a stumbling block for adequate consideration being given the call by Ogunniyi (1988), Kent and Towse (1997), and Jegede (1997) to include indigenous technologies in the African science education experience.

Factors that students say had an influence on their decision to study science and engineering

Finally, I asked students to tell me which factors they thought most influenced their decision to pursue a career in science and engineering. Overall, personal motivation, receiving a bursary, access to information, and participation in a school science competition or science club were the four broad themes that emerged from the analysis of the factors which students reported most influenced their decision to study science or engineering. These results are consistent with the Woolnough et al. (1997) findings. Furthermore, these themes were identical for the male, engineering and non-African subgroups. Within subgroups, however, some interesting differences emerged. While engineering students were motivated by a need to know how things work, science students cited information received at a careers open day and involvement in a school science competition as the factors that most influenced their career decision. This is consistent with the view presented earlier that, unlike engineering, science as a career is less concrete and that students might need help with identifying a specific interest. Similarly, African students also cited information received at a careers open day and involvement in a school science competition as the factors that most influenced their career decision.

The results of this study, I believe, are consistent with the generally held view that distinctly different strategies are required to motivate students positively towards careers in science. I believe however, that we have in our favour the fact that the students who have chosen to study science and engineering generally reflect a favourable attitude towards science—science is easy, exciting, and they wish to know more about it. Students viewed science as useful in everyday life and equally useful for boys and girls—sentiments which were also expressed by students in the Kent and Towse (1997) study. Students were unsure as to whether they need science to get a good job or whether scientists and engineers have more status in their community than people in other professions. This latter trend is particularly interesting as it is contrary to the findings of Woolnough et al. (1997). This suggests that a favourable attitude towards science and a particular view about the role of science, rather than personal gain, could influence students positively towards careers in science. This is consistent with the justification provided in Chapter 2 (pg. 10) for why it is desirable to develop and nurture an interest in science amongst South Africans.

Conclusion

The findings of this study are, in my view, consistent with the view that we need a differentiated approach when trying to understand why students might be motivated towards further study and careers in science and engineering (Robertson, 2000; Woolnough, 1994; Woolnough et al., 1997). It suggests that Woolnough's model of blending individualistic and structural aspects of students' experiences can provide some important insights about who they are, where they've come from, and what we need to do to feed their interest in science. Furthermore, the findings of this study give support to the view that what parents say, the information that learners have access to, and what teachers and career counselors do, plays an important role in influencing the career decisions that students make. The generally poor commitment on the part of schools to expose students to non-curriculum activities and events that popularize science is cause for concern. Recommendations were made with respect to including parents and senior learners in initiatives to channel information about possibilities for future study, about opportunities for bursaries, about people in science, and about science in everyday life into schools and homes. It is concluded that there is an urgent need for special attention to be given to how schools can access, utilize and make successful use of such resources.

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APPENDIX

QUESTIONNAIRE USED

FOR OFFICE USE

1-4

SURVEY : FACTORS AFFECTING CAREER CHOICE

INSTRUCTIONS

In Section A you are asked to provide some background information about yourself.

Section B is concerned with your high school science experience.

IN SECTION B, PLEASE REMEMBER THAT WHEN WE ASK ABOUT YOUR SCHOOL SCIENCE SUBJECTS, WE DO NOT MEAN MATHEMATICS OR COMPUTER SCIENCE.

YOU MUST THINK ABOUT YOUR FAVOURITE NATURAL SCIENCE SUBJECT AT SCHOOL (WHICH COULD HAVE BEEN BIOLOGY OR GEOGRAPHY OR PHYSIOLOGY OR PHYSICAL SCIENCE ETC.). THEN, ANSWER THE QUESTIONS WITH REFERENCE TO THIS ONE FAVOURITE SCIENCE SUBJECT ONLY.

Please write the name of your favourite school science subject here:

____

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SECTION A

In this section you are asked to provide some background information about yourself, the science subject/s that you studied in matric (or A-levels), and what you are studying now at University.

1. **I am** *(please tick the appropriate box)*

Female	1	Male	2	5

2. **My home language is** *(please tick the appropriate box)*

Afrikaans	01	Tsonga	07	
English	02	Tswana	08	
Ndebele	03	Venda	09	
Nothern Sotho	04	Xhosa	10	
Southern Sotho	05	Zulu	11	
Swazi	06	Other (please specify):	12	
		______________________		6-7

3. **I passed Matric (or A-levels) in**

19 ____ 8-9

4. **I matriculated (or completed my A-levels) at** *(please give the full name, and place, of your last school)*

____

5. **My matric (or A-levels) science subjects were** *(from the list below, please tick all science subjects that you did at school and also indicate whether you did these subjects on the Higher (HG) or Standard Grade (SG). A-levels students please tick subjects only).*

Subject		***Grade***				
Biology	1	HG	1	SG	2	10-12
Geography	2	HG	1	SG	2	13-15
Physical Science	3	HG	1	SG	2	16-18
Physiology	4	HG	1	SG	2	19-21
Agricultural Sciences	5	HG	1	SG	2	22-24
Other (please specify):	6	HG	1	SG	2	25-27
______________________						
Mathematics	7	HG	1	SG	2	28-30
Computer Science	8	HG	1	SG	2	31-33

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6. I decided to do at least one science subject until matric because *(please tick all boxes that apply)*

I liked General Science in standards 6 and 7 and wanted to know more about science.	☐ 1	34
I had no choice. The school decided which subjects I should do.	☐ 1	35
My parents insisted that I do a science subject at school.	☐ 1	36
All my friends did a science subject at school.	☐ 1	37
I thought I might need a science subject to get into University one day.	☐ 1	38
I knew I would need a science subject to have a career in science or engineering.	☐ 1	39
I always did well in mathematics and thought a science subject would be easy.	☐ 1	40

7. I am in my very first year of registration at any University *(please tick the appropriate box)*

Yes ☐ 1   No ☐ 2   41

8. I am currently registered in the *(please tick the appropriate box)*

UNIVERSITY OF CAPE TOWN		UNIVERSITY OF STELLENBOSCH	
Engineering Faculty	☐ 11	Ingenieurswese	☐ 21
Science Faculty	☐ 12	Natuurwetenskape	☐ 22
Other (please specify):	☐ 13	Other (please specify):	☐ 23
____________________		____________________	42-43

9. I intend to major in the following subject/s *(to be completed by Science Faculty Students only)*

____

10. In five or six years I expect to be working as *(please tick one box only)*

a Scientist (eg. botanist, geologist)	☐ 01	an Engineeer	☐ 07
a Doctor	☐ 02	a Laboratory Technician	☐ 08
an Architect	☐ 03	an Actuary	☐ 09
a Farmer	☐ 04	a Building Contractor	☐ 10
a Science Teacher	☐ 05	a Computer Scientist	☐ 11
Other (please specify):	☐ 06		

____________________   44-45

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11. While I was in high school, my mother worked as *(please write down your mother's occupation)*

____________________________________ 46

12. While I was in high school, my father worked as *(please write down your father's occupation)*

____________________________________ 47

13. The person who had the most influence on my career choice was *(please tick one box only)*.

my mother	☐	1
my father	☐	2
another relative	☐	3
a relative who is an engineer/scientist	☐	4
a careers counsellor	☐	5
a teacher	☐	6
a friend	☐	7
a scientist or engineer who visited my school	☐	8
other (please specify) ____________________	☐	9

48

14. In my last three years of high school, I had a part-time job (either in the afternoons after school or in the school holidays) as *(please briefly describe the jobs that you had)*

job 1: ____ 49

job 2: ____

job 3: ____

15. The statements below refer to science in general (i.e. not to one particular science subject). Read each statement carefully and tick the box which best describes how you feel. *(please tick only one box per statement)*

	Strongly Agree	*Agree*	*Not Sure*	*Dis-agree*	*Strongly Disagree*	
	5	4	3	2	1	
Science is useful in everyday life.	☐	☐	☐	☐	☐	50
Science is exciting and I want to know more about it.	☐	☐	☐	☐	☐	51
I need science to get a good job.	☐	☐	☐	☐	☐	52
Science is difficult and I really have to work hard at it.	☐	☐	☐	☐	☐	53
Science is more useful (or important) for boys than for girls.	☐	☐	☐	☐	☐	54
Scientists and engineers have more status in my community than people in other professions.	☐	☐	☐	☐	☐	55

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SECTION B

This section is concerned with your high school experience of science subjects. In the following questions, you are asked to describe (a) the facilities that were available to you, (b) activities that may have taken place in lessons in your favourite science subject, and (c) the factors that you think most influenced your decision to study science or engineering.

a) School Facilities

16. Which of the following did you have at your last school? *(please tick all boxes that apply)*

a well-equipped science laboratory	☐	1	56
a well-equipped computer laboratory	☐	1	57
a careers information library	☐	1	58
a careers guidance teacher	☐	1	59
an active science club or society	☐	1	60
a regular display of students' science projects	☐	1	61
a noticeboard for career information	☐	1	62
a noticeboard for interesting science material	☐	1	63

17. While you were at high school, did any of the following events happen? *(please tick the appropriate box for each item)*

	Yes 1	*No* 2	
You entered a project in a school science competition.	☐	☐	64
You joined a school science club.	☐	☐	65
Your school arranged a Science Open Day where other students and parents could view a project you did in a science class.	☐	☐	66
An engineer visited your school to talk to you about the work that he/she does.	☐	☐	67
A scientist visited your school to talk to you about the work that he/she does.	☐	☐	68
Your school arranged for you to visit an engineering company to see what kind of work they do.	☐	☐	69
Your school arranged for you to visit a science department at a university or technikon to see what kind of work they do.	☐	☐	70
Your school arranged for you to visit a Careers Open Day at a university or technikon.	☐	☐	71

18. Think of your favourite science subject in matric. How many students were there in your class? *(please tick the appropriate box)*

1 - 10 students	☐	1	31 - 40 students	☐	4	
11 - 20 students	☐	2	41 - 50 students	☐	5	
21 - 30 students	☐	3	more than 50 students	☐	6	72

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b) School Science Classroom Activities

19. Think of your favourite science subject in matric. Which of the following activities best describe what usually happened in lessons in this subject? *(please tick all boxes that apply)*

Our teacher demonstrated experiments while students watched.	☐	1	73
Our teacher had no time to demonstrate experiments.	☐	1	74
Our teacher always stressed the facts of science.	☐	1	75
Our teacher always stressed the importance of working in a systematic way.	☐	1	76
Our teacher often explained how science relates to everyday life.	☐	1	77
The class always wrote a test after each section of the syllabus had been completed.	☐	1	78
The class often discussed career opportunities in science and engineering in class.	☐	1	79
Our teacher allowed students to go beyond the regular laboratory exercises and do some experimenting of their own.	☐	1	80

20. Think about the lessons in your favourite science subject in matric. Now read each statement below and tick the box that best describes how you feel. *(please tick only one box per statement)*

	Agree 3	*Not Sure* 2	*Dis-agree* 1	*Not Applicable* 0	
The most exciting aspect of school science was learning about scientific facts.	☐	☐	☐	☐	81
I felt happiest when my teacher gave clear instructions to follow when doing laboratory experiments.	☐	☐	☐	☐	82
I felt happiest when our teacher had lots of notes prepared for us.	☐	☐	☐	☐	83
Observing laboratory experiments systematically, and writing up results correctly, helped me to understand the logic of science.	☐	☐	☐	☐	84
I felt happiest when our teacher had activities planned for us.	☐	☐	☐	☐	85
I liked to solve scientific problems on my own rather than work with my friends.	☐	☐	☐	☐	86
I felt happiest when our teacher included students' suggestions, ideas, and discussions in the lesson.	☐	☐	☐	☐	87
I felt happiest when my teacher allowed me to plan my own laboratory experiments in class.	☐	☐	☐	☐	88
The most exciting aspect of school science was doing scientific experiments.	☐	☐	☐	☐	89

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21. Read each of the following statements carefully. Please tick the box that best describes how you feel. *(please tick only one box per statement).*

	Agree 3	*Not Sure* 2	*Dis-agree* 1	*Not Applicable* 0	
Being involved in a school science club was great fun.	☐	☐	☐	☐	90
I learnt a lot about science by participating in a school science competition.	☐	☐	☐	☐	91
Engineers and scientists who visited my school made science very exciting for me.	☐	☐	☐	☐	92
I was encouraged to continue with science at school because my parents took an interest in my school science projects.	☐	☐	☐	☐	93
Having a holiday or part-time job related to science or technology encouraged me to continue with science at school.	☐	☐	☐	☐	94

c) Factors which influenced your career choice

22. Described below are factors that <u>may</u> have influenced your decision to study science or engineering. Please tick the box that best describes the influence that <u>each item</u> may have had on your decision to study science or engineering. *(please tick only one box per item)*

	Positive Influence 3	*Negative Influence* 2	*Not Sure* 1	*Not Applicable* 0	
I read an article about a career in science or engineering	☐	☐	☐	☐	95
I received a bursary to study science or engineering	☐	☐	☐	☐	96
Science allows me to be creative, to build and design things	☐	☐	☐	☐	97
At school I could follow my own interests in science	☐	☐	☐	☐	98
I always did well in mathematics and science at school	☐	☐	☐	☐	99
I enjoy making things and fiddling with gadgets	☐	☐	☐	☐	100
Doing science is an intellectual challenge	☐	☐	☐	☐	101
Involvement in a school science club	☐	☐	☐	☐	102
Scientists and engineers have well paid jobs	☐	☐	☐	☐	103
I am interested in knowing how things work	☐	☐	☐	☐	104
A holiday or part-time job related to science or engineering	☐	☐	☐	☐	105
Involvement in a school science competition	☐	☐	☐	☐	106
I received information at a Careers Open Day about a career in science or engineering	☐	☐	☐	☐	107