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An empirical evaluation of students' perceptions of the nature of science: A comparison between groups.

by

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAAA	American Association for the Advancement of Science
EXPO	Exposition for Young Scientists
FRD	Foundation for Research Development
HoR	House of Representatives
NOSS	Nature of Science Scale
S&T	Science and Technology
STS	Science, Technology and Society
TIMSS	Third International Mathematics and Science Study
TOUS	Test on Understanding Science
USA	United States of America
VOSTS	Views of Science-Technology-Society

ABSTRACT

In 1991 Evans and Schibeci used a modified *Views of Science-Technology-Society* (VOSTS) instrument to assess 434 Australian students' views on selected aspects of the Science-Technology-Society (STS) theme. In South Africa, Parker and Rochford (1995), and the writer Edwards et al. (1997) conducted and published further corroborative studies with more than 1400 students.

Set in the context of the debate on the "traditional" and "contemporary" models of the nature of science (after Palmquist and Finley, 1997), this study measures, compares and interprets the response patterns of five convenient sample groups to 26 items on the modified VOSTS instrument. The three subscales measure students' perceptions of the *definition of science; scientific method* and *how scientific knowledge changes*. The reliability of the instrument was computed for Cape Town students using Cronbach's coefficient which yielded $\alpha = 0.78$; and its content had been shown to be inherently valid at the time it was developed.

A self-completion questionnaire was administered by the writer to four Cape Town student samples in 1995 during normal periods of instruction at two high schools, a technikon and a college of education. The samples comprised 320 year 10 high school science students, 340 year 12 high school science students, 108 electrical engineering students, and 55 first year college of education science students respectively. The 434 year 10 Australian students' (sample 5) responses were compared with the responses of their South African counterparts.

In order to determine statistically significant differences between the response frequencies of the sample groups on the 26 items, the χ^2 - test statistic was used. If fewer than five

responses were recorded in a particular category, then the Mann-Whitney U-test was employed as an alternative non-parametric test. These statistical tests resulted in all four null hypotheses being rejected, in other words, there were statistically significant differences between the response patterns of the sample groups to the importance of at least some of the 26 items on the three subscales of the modified VOSTS instrument.

It was found that the five samples, on average, attributed the greatest importance to items 1F (77%), 2E (75%) and 3A (66%) on the three subscales respectively, i.e. science was perceived as *exploring the unknown and discovering something new about our universe* - which represents a "realistic" perspective; the scientific method was perceived as *testing and retesting, proving something true or false in a valid way* - which represents a "traditional" approach; and scientific knowledge was perceived as changing *because new scientists disprove the theories or discoveries of old scientists* - which characterises the falsificationist position, also a "traditional" approach.

The findings suggest that the instrument was sensitive to detecting areas of agreement and disagreement between the responses of the various groups surveyed. The empirical evidence also supports the feasibility of identifying and/or implementing some of the stated objectives of South Africa's new Curriculum 2005, especially in the learning areas of Natural Sciences and Technology. The samples of South African students tended to hold more "contemporary" views of science, which might make the goal of scientific literacy much easier to achieve . On some of the items, however, "traditional" views were expounded by the students. This should not be seen as a contradiction, but rather as support for the widely held view that there is no single view of the nature of science.

CHAPTER 1

INTRODUCTION

1.1 The Challenge of the Nature of Science for Teaching Science and Technology

In their recent investigation into preservice teachers' views of the nature of science during a postbaccalaureate science teaching programme, Palmquist and Finley (1997:595) explained why science teachers need to recognise the nature of scientific endeavour and how it relates to science teaching. Their most recent research concluded that most of the preservice teachers had definite views of various aspects of the nature of science which were either "traditional" or "contemporary". Their work was a sequel to the studies of several earlier investigators, such as Aikenhead, Flemming and Ryan (1987); Aikenhead (1988); and Aikenhead and Ryan (1992); and it is in this particular context that the writer's current study was conducted in Cape Town, and is now presented.

The findings reported in this dissertation have already been published recently as two full-length articles in the refereed *Proceedings* of two international Conferences: in Poland in 1998, and in Zimbabwe in 1999; as well as a separate third article in the European journal *Senzor* in 1997. Photocopies of these two Conference papers and the journal article are attached and reproduced in Appendix A.

1.2 Statement of the problem

This investigation is set in the context of the recent release of definitive publications, by the American Association for the Advancement of Science (1999a and 1999b) on the current understanding of the nature and methodology of science and technology.

In 1987 Aikenhead et al. developed an instrument for determining Views of Science-Technology-Society (VOSTS) among high school students. The content was defined by the domain of science-technology-society (STS) topics appropriate for high school students. A pool of 114 items was developed by producing choices which were empirically derived from students' writing and from a series of interviews. These were administered to more than 2000 grade 11 and 12 students in Canada.

Subsequently, in 1991, Evans and Schibeci used a modified VOSTS instrument to assess 434 Australian students' views on selected aspects of the STS theme. Then in South Africa Parker and Rochford (1995), and the writer Edwards and Rochford (1997) conducted further corroborative studies with more than 1400 local students.

The modified VOSTS instrument used 26 items to measure student views on three coherent scales, commencing with the lead headers: **"Science is...", "The scientific method is..."** and **"Scientific knowledge..."** respectively. These are reproduced as attachments in Appendix B.

In the light of the emerging, diverging "traditional" and "contemporary" models of the nature of science, as described by Palmquist and Finley (1997), the problem selected for this study was to compare, contrast, interpret and explain the perceptions of different groups of science and technikon students towards selected aspects of the STS theme using the three modified VOSTS scales. It set out to evaluate and interpret the South African and Australian responses of five convenient sample groups, in the age range 15 to 19 years, in respect to the importance of 26 items on the modified VOSTS instrument of Evans and Schibeci (1991). Its three subscales purported to measure student perceptions of: *the definition of science* (10 items); *the scientific method* (11 items); and *how scientific knowledge changes* (5 items).

1.3 Importance of the study

At the same time as the work of Ogunniyi (1998;1999), this study was carried out as one of many other recent inter-related local investigations into people's perceptions of the world of science and technology (S&T); the effects of science and technology on traditional beliefs and culture; young people's attitudes towards science and technology in Africa; the popularisation of science and technology; the state of science and technological literacy in Southern Africa; and the role of the communications media in the public understanding of science and technology.

These studies were a sequel to the release, by the Foundation for Research Development (1996), of science-and-technology indicators showing underperformance in the South African context, as described in more detail below in sections 1.4 and 1.7. Laugksch (1999: 12-14) has presented pertinent arguments for the promotion of scientific literacy in both the macro and micro contexts:

- The macro view deals with benefits to the nation, science, or society. He argues that economic competitiveness and sustainability depend on a good research and development programme which produces hi-technology products. This can be achieved only by having a good cadre of technical personnel that is the product of a scientifically literate nation. Support for science itself is also enhanced, and the public's expectations of science may be tempered if there is a greater level of scientific literacy. A scientifically literate nation can also influence, and be of benefit to, science policy-making and democratic decision-making practices.
- The micro view looks at the benefits of scientific literacy to individuals. These include awareness about correct diets, ill-effects of smoking, screening programmes, or safety in the home and at work. Scientifically literate individuals are also an asset in the workplace as technical developments become more common. Other arguments are concerned with the intellectual, aesthetic and moral benefits of scientific literacy to individuals.

Laugksch (1999: 2-3) also identified four main interest groups who have a shared interest in the promotion of scientific literacy:

1. The science education community, including curriculum developers and professional science education associations, is concerned with the relationship between formal education and scientific literacy.
2. Social scientists and public opinion researchers are concerned with science and technology policy issues.
3. Sociologists of science, and science educators who use a sociological approach to scientific literacy, are concerned with the construction of authority with respect to science.

4. The in- and non-formal science education community, and those involved in general science communication, include personnel at science museums, botanical gardens and zoos, and members of teams at science exhibitions or displays. Radio and television personnel involved in science programmes, as well as science journalists complete this group.

The scientifically literate individual also understands the nature of scientific knowledge, applies appropriate scientific concepts and theories when necessary, uses processes of science to solve problems, upholds scientific values, understands the interaction between science, technology and society, and has developed numerous manipulative skills and a richer view of the universe (cited by Laugksch, 1999: 4-5). This is of particular relevance to the present study, with its important focus on the VOSTS.

1.4 Background of the study

South Africa ranks 93rd out of 178 countries on the United Nations Human Development Index (MacGregor, 1997:15). Should our matriculation examination results serve as an indicator of the development of our human resources, then it is unacceptable that only 47.4% of all matriculants passed the final examination in 1997, with a modest improvement of 3.3% in 1998 (Cape Argus, 8 January 1999: 5). The introduction of a uniform examination at provincial level has merely highlighted the disparities of the past. Thus, these results should be placed in the context of the many problems which beset education, for example, inadequate resources, large class sizes, the lack of a culture of teaching and learning, teacher redeployment, etc. However, it should also be noted that South Africa spends about R35 billion on education. This is about 6.6% of our Gross

Domestic Product, compared with 5.8% in developed countries (MacGregor, 1997:17). A massive investment in human capital such as this should achieve better results.

One recent initiative has been the introduction of Curriculum 2005. The former Minister of Education, Professor SME Bengu, indicated that the curriculum will shift from a content-based to an outcomes-based one (Curriculum 2005, 1997: 1). The aim is to prepare competent future citizens who will have the necessary skills to meet the challenges of the 21st century. Education and training will be integrated and eight areas of learning have been established for which new curricula must be developed. The introduction of Curriculum 2005, amidst all the other pressing problems in the education sector, remains a contentious issue in 1999.

In July 1999 the new Minister of Education, Professor Kader Asmal, expressed his concern at the poor quality of learning in many parts of our education system, especially the poor performance of learners in internationally standardised tests of mathematics and science (Statement by the Minister of Education, Tuesday 27 July, Asmal, K., 1999: 4).

Two of the eight learning areas in the proposed new curriculum are *Natural Sciences* and *Technology*. The state's recognition of the importance of science and technology (S&T) is commendable. The development of responsible, sensitive and ***scientifically literate*** (my emphasis) citizens who can critically debate scientific issues is one of the stated rationales for the natural sciences (Department of Education : Learning Area : Natural Sciences, 1997: 52). It is also anticipated that learners will be able to understand the interaction between science, technology and socio-economic development as a specific outcome of the natural sciences (p55).

The White Paper on Science and Technology was published in 1996. It states that S&T are considered to be central to creating wealth and improving the quality of life in contemporary society. The policy thrust of the White Paper is also said to be in harmony with that of the White Paper on Education and Training in its identification of investment in mathematics, science and technology as a fundamental goal (p6). According to an international research study, the Third International Maths and Science Study (TIMSS), a cross-sectional sample of South Africa's 13 year-olds - many of whom were disadvantaged in the tests by being required to read and respond only in English - had the lowest average scores in Mathematics and Science out of 41 participating countries (Gray, 1997 :167-170). Although this study is not completely conclusive, nevertheless it should prompt a re-examination of teaching and testing methods in these two disciplines, while also highlighting the importance of S&T as outlined above.

South African citizens today are part of a democratic decision-making process. These require not only oral and written communication skills, but also knowledge based on science and technology when technical issues arise. For example, rapid development is taking place along our coastline, sometimes on environmentally sensitive land - but should this be allowed? Informed decisions can be taken only after all stakeholders are conversant with the scientific and technological facts of a feasibility study.

Secondary and tertiary students should develop critical thinking skills because they are the leaders and decision-makers of tomorrow. It is also important that they begin to understand the numerous interactions and interplay between science, technology and society. Thus, an evaluation of students' perceptions of selected aspects in the STS debate might therefore identify some of their preconceived ideas. The results of such a study might be used, in conjunction with other studies, to establish a framework in which one of the stated rationales of the natural sciences can be realised, viz. to develop responsible, sensitive and scientifically literate citizens. This might possibly assist the present developers of Curriculum 2005, especially in the S&T learning areas.

1.5 Purpose of the study

This empirical study evaluates students' perceptions of selected aspects of the science-technology-society theme. It begins by comparing the South African and Australian responses of five sample groups, in the age range 15 to 19 years, to the importance of 26 items on the modified views of science, technology and society (VOSTS) instrument of Evans and Schibeci (1991) which is attached in Appendix B.

The present study also specifically compares the perceptions of four Cape Town samples of 320 standard 8 (year 10) students, 340 standard 10 (year 12) students, 108 electrical engineering students, 55 first year college of education students and one sample of 434 year 10 Australian students on the three subscales of the modified VOSTS instrument. Initially, the four local samples were surveyed between January and June 1995. At that particular time, the modified VOSTS was already established as a valid and reliable instrument for the purposes of this study. The Australian sample, taken from Evans and Schibeci (1991), was used for comparison purposes with the South African standard 8 sample.

1.6 Development of the study

In order to overcome the problem of researchers assuming that there is no ambiguity in test items, Aikenhead et al. (1987) developed the original VOSTS instrument in Canada, as described earlier on page 2.

In 1991, using a modified VOSTS instrument, Evans and Schibeci assessed 434 year 10 Western Australian pupils' views on selected aspects of the STS theme in Perth. In a South African corroborative study in 1993, Parker et al. (1995) then used the modified VOSTS instrument to measure the views held by 82 young aspirant scientists and technologists, as well as by 391 mainstream senior high school students in Cape Town. They found six significant response differences (out of 26) to VOSTS items between the two samples. However, they found no significant differences between the percentage frequencies of the responses of Perth and Cape Town samples of mainstream students.

In 1994 the modified VOSTS was then administered to 499 female and 498 male 15- to 17- year old students in South Africa. The findings, authored by the writer of this dissertation, were analysed in 1995 by the writer, and were subsequently published in full in the international journal ***Senzor*, 1997, volume 3, pages 2-9,** a copy of which is attached in Appendix A.

This current study therefore expands on the earlier work of Evans and Schibeci (1991) in Australia, Parker et al. (1995) and Edwards et al. (1997) in Cape Town. It compares the response frequencies of secondary and tertiary students to the importance of statements which purport to measure student perceptions of *the definition of science*, *scientific* *method* and *how scientific knowledge changes*; but it also interprets the responses more widely in the context of both "traditional" and "contemporary" views of various aspects of the nature of science, after Palmquist and Finley (1997), as well as the interpretive framework of Aikenhead and Ryan (1992), and in the context of Ogunniyi (1999) and AAAS (1999).

1.7 The social importance of the research context

Bybee et al. (1991 : 144) cite the following quotation which summarises the reasons for an emphasis on science and technology in a social context:

> *Science and technology are integral parts of today's world. Technology, which grows out of scientific discovery, has changed and will continue to change our society. Utilisation of science in the solution of practical problems has resulted in complex social issues that must be intelligently addressed by all citizens. Students must be prepared to understand technological innovation, the productivity of technology, the impact of the products of technology on the quality of life, and the need for critical evaluation of societal matters involving the consequences of technology (National Science Board, 1983 : 44).*

The Foundation for Research Development (FRD) has published S&T indicators in the South African context in 1996. For example, Japan had 71 scientists for every 1000 people whereas South Africa had only 3.3 for every 1000. A survey of people's attitudes towards S&T yielded 75% positive responses from people with post-matriculation education. Thus, improved public awareness depends on the level of education. In addition to this, the indicators also showed that a sample of South Africans performed poorly on the survey of the public understanding of the natural and environmental sciences. An average score of 5.2 correct answers out of 12 was obtained (FRD News, October 1996).

The stated policy of the South African government is that science and technology has a critical role to play if we are to realise a sustainable economic growth rate. S&T make significant contributions in important sectors of the economy, e.g. health, agriculture, transportation, materials and energy production, population control, water and environmental management, etc. Therefore students should have a good understanding of these areas since they span across subject disciplines at school and tertiary level. The various curricula should emphasise more than just the acquisition of facts and theories. Students must be encouraged to understand the nature of scientific knowledge, the purposes it serves and how technological advancement is linked to all this. They must know that society influences S&T, as well as how S&T influences society.

At a Conference on Promoting Public Understanding of Science and Technology in Southern Africa (4-7 December 1996), several speakers argued for the development of S&T, as described in Ogunniyi (1998):

- Taiwo (pp61-69) proposed that the nations of Africa embrace the doctrines of the scientific approach so that they are no longer bystanders but active participants in global affairs in the 21st century.
- Yandila (pp96-99) suggested that modern S&T offers immense possiblities for solving problems which impede economic and social development in the African context.
- Rollnick (p111) concluded that one of the main causes of low science and technological literacy in South Africa is due to the historic exclusion of the majority of the population from the field of S&T. A change of attitude as well as the acquisition of skills and knowledge is needed to turn the situation around.

1.8 The specific aims of the current research are:

- To measure and compare the percentage frequencies of perceptions of secondary and tertiary level students on the three subscales of the modified VOSTS instrument.
- To establish whether any statistically significant differences exist between the frequencies of perceptions of the various sample groups.
- To suggest and use an interpretive comparative framework for analysing the empirical results of the study.
- To discuss any possible applications of these findings for the implementation of Curriculum 2005 and for the two areas of learning of *Natural Sciences* and *Technology*.
- To make any additional recommendations that may arise out of the study.

1.9 Hypotheses

Four null hypotheses are tested in this study. These test whether any statistically significant differences exist between the frequencies of the perceptions of the various sample groups with respect to the relative importance of each one of the 26 item statements given on the modified VOSTS instrument. The null hypotheses for the five sample groups are stated in full in Chapter 3.

1.10 Clarification of terms

Science-technology-society (STS) : All citizens should be capable of understanding and critically analysing and evaluating issues at the modern science/technology/society interface (Zoller and Ben-Chaim,1994:77).

Scientific and technological literacy : Literate learners are those who have an understanding of the nature and the limits of science and technology, a mastery of the basic conceptual knowledge in the major disciplines and a sense of the social impact/implications of S&T (cited by Schibeci and Kissane, 1994:48).

Modified VOSTS instrument : This consists of three subscales commencing: ***"Science is ...", "Scientific knowledge is ..."*** and ***"Scientific knowledge ..."***. They comprise a total of 26 item statements that must be rated "major part", "minor part", "no part" and "I don't know" by respondents.

Science : The organised body of knowledge in Biology and Physical Science (Physics and Chemistry).

"Traditional" and "Contemporary" Models of the Nature of Science:

These are defined in terms of five key realms of the nature of science (scientific theory, scientific knowledge, scientific method, scientific laws, and the role of scientists), as described and attached in Appendix C.

1.11 Glossary of terms from the Philosophy of Science

Constructivism: The view that the subject matter of scientific research is wholly or partly constructed by the background theoretical assumptions of the scientific community, i.e. it is not independent of our thoughts and theoretical commitments.

Deduction: The process of deriving statements (conclusions) that follow necessarily from an initial set of statements.

Empiricism: The view that all knowledge is based on or exhausted by what is known by sensory experience.

Epistemology: The study of the nature, origins, objects, and limitations of knowledge.

Falsification(ism): The process of showing a claim to be false. According to Popper, for a claim to be scientific it must be possible to specify which observations would falsify it.

Induction: Simple induction is the process of drawing a conclusion, or estimating the support for a hypothesis, on the basis of observed instances of past events.

Logical positivism (or empiricism): An attempt to interpret science and philosophy in terms of verification, i.e. empirically show a claim to be true.

Ontologogy: Used in the sense of the entities postulated by a particular theory (and also it can be used in the sense of a branch of metaphysics that studies the nature of existence).

Realism: The view that phenomena of a specified sort exist independently of being thought about and/or are largely non-mental in character.

(Boyd, Gasper and Trout, 1993: 775-781)

1.12 Limitations of the study

This study has used the modified VOSTS instrument to gather data from only five convenient samples of high school, college of education and technikon students. The items in the instrument deal with only perceptions of selected aspects in the STS debate, i.e. *defining science, scientific method* and *how scientific knowledge changes*.

The study provides empirical evidence for differences or consensus among student views of science, scientific method, etc. It does not purport to give right or wrong answers, since the original VOSTS instrument was developed from the perspective of the students' viewpoints.

1.13 The assumptions of the study

It is assumed that all the participating senior students had a basic grasp of, and background in, junior level General Science, and thus were able to make an informed rating of the relative importance of each of the 26 items. The study also assumes that each student understood the wording of each item in the same manner, and responded seriously, since the data was collected during formally supervised classroom time.

1.14 Research approach

The data was collected during normally scheduled lesson or lecture time in Physical Science, Biology, Mathematics and Electrical Engineering studies at the high schools, college of education and technikon respectively. The instrument required approximately 20 minutes to administer and complete. The co-operating teachers and lecturers reported that the students responded seriously to the task assigned to them.

The data were analysed using the χ^2 - test and Mann-Whitney U-test in order to establish statistically significant differences between the response frequencies of the various sample groups. Both of these two statistical procedures are non-parametric, with the Mann-Whitney U-test being used when certain categories of items attracted fewer than five responses.

1.15 Organisation of the remainder of the dissertation

The chapters which follow are arranged thus:-

Chapter Two	A review of the relevant literature pertaining to this study is outlined.

Chapter Three	This chapter presents details of the research method, a description of the samples, and the measuring instrument; and it also describes the data collection method.
Chapter Four	The results are summarised and tabulated. The findings are presented with a brief discussion of the emerging trends.
Chapter Five	The results are discussed and analysed in more detail.
Chapter Six	The study is concluded, offering recommendations and implications for further research.

1.16 Chapter Summary

In this chapter an overview of the study has been presented. The problem, its setting and importance have been given, the purpose and hypotheses of the study outlined, the origin and background sketched, and the importance of the study highlighted. Furthermore, the aims of the study have been presented, some terms clarified and the limitations of the study stated. Finally, the assumptions have been given and the research approach introduced.

Chapter two presents a literature review of the relevant studies and theories pertaining to this study, and critically evaluates the strengths and limitations of the methodology and findings of these earlier studies. It concludes by showing how the present study might be able to help corroborate, or fill the gaps in, the current available published literature.

CHAPTER 2

LITERATURE REVIEW

This chapter comprises two sections:

- Section 2.1 presents a review and critique of *related research findings* on student perceptions of the nature of science in the STS domain, as well as other findings related to the nature of science.
- Section 2.2 presents an outline of the *theoretical framework* underpinning the analysis and interpretation of the empirical findings of this study.

2.1 Related research findings: a review and critique

In 1987 Aikenhead, Fleming and Ryan produced a four-part series of articles which detailed a study of Canadian high school students' viewpoints on STS topics: the methods and issues in monitoring student views (Aikenhead et al., 1987); the interaction among science, technology and society (Fleming, 1987); the characteristics and limitations of scientific knowledge (Aikenhead, 1987); and the characteristics of scientists (Ryan, 1987).

A sample of 10800 students in their graduating year was drawn in a stratified manner from across Canada. Out of the 10800 student responses, about 236 addressed one of 46 statements based on 16 major topics found in the epistemology and sociology of science literature (Fleming, 1987:163). A random 30% of the responses were analysed to tease out common viewpoints held by the students.

The authors argued in their first article that while the VOSTS instrument was developed with its content reflecting the epistemology of science of earlier theoretical models from the philosophy of science (p148), it also drew upon the social context of science. The STS topics emphasised cognition over attitude, but it was also open to further development since it did not include all the important aspects of STS education. The content validity of the VOSTS instrument was also hampered because there was no consensus regarding the legitimate domain of STS content. The authors also proposed that to improve the understanding of student viewpoints, a semi-structured interview technique may be employed (p155). Further study could include comparisons between different cultural groups or groups of educators, or it may serve as a pre-instruction investigation to inform teachers and curriculum developers.

In the second article Fleming (1987:167) posited the view that the students in the study generally failed to differentiate between the roles of science and technology. The blurring of the two roles to create a new social enterprise is referred to as technoscience; for example, scientific research is often equated with finding cures for diseases. A point for further research may be to locate the source of this belief, i.e. does it originate from the school curriculum, or from the mass media, etc.?

The third article discussed the characteristics and limitations of scientific knowledge. Seventy five percent of the students viewed scientific classification schemes as being more epistemological than ontological, but only 45% viewed scientific models as epistemological. Almost 100% of the students believed that scientific knowledge is tentative, but their reasons were varied (p484). Many diverse definitions of the scientific method were given, the most consistent view being that it is "following prescribed laboratory procedures". About 75% of the students believed that social interactions within the scientific community can affect the knowledge that scientists discover.

The fourth article reported that the majority of students perceived that scientists were concerned with the potential effects of their discoveries, while 38% apportioned the responsibility for the harm that might result from scientific discoveries to the user (p495). Most students (75%) felt that scientists should be responsible for reporting their discoveries to the general public. A large group of students perceived scientists as unbiased and objective, a quality which is transferable to eveyday life (p500). On the question of the unequal gender distribution of scientists, 28% of the students felt that it is not justifiable.

In Ryan and Aikenhead's (1992) study reporting students' preconceptions about the epistemology of science based on VOSTS, some basic nature of science tenets are implicit:

- The social purpose of the scientific enterprise is to generate new knowledge for its own sake.
- Technology is not applied science.
- An ontologic perspective consistent with logical positivism is naïve.
- Consensus among self-appointed experts is the basis of scientific knowledge.

(cited by Alters, 1997:41)

Subsequent to the development of the VOSTS instrument, a plethora of studies have evolved using some items from the pool of 114 VOSTS items. A summary and critique of the results from some of the relevant studies is presented below.

Zoller et al. (1990: 19) used a questionnaire comprising four representative statements from the VOSTS inventory to assess the STS beliefs of 377 high school students in British Columbia. They found that a substantial change in the viewpoints of the students occurred when they were exposed to a science and technology course. Some of the goals of a typical STS course were attained, and the data obtained could be used for future educational policy-making concerning STS curricula (p34). The different roles of science and technology were not clearly distinguished by the students. The authors concluded that the VOSTS instrument was useful for assessing student viewpoints on STS issues, but its use in cross-cultural studies must take into account the context in which the study occurs.

In the United States of America, Rubba and Harkness (1993: 407) investigated 26 pre-service and 19 in-service secondary science teachers' beliefs about STS, particularly the nature of science and technology. The majority of students had views of science that were classified as having merit, 54% of pre-service teachers had realistic views on the process of doing science while 42% of in-service teachers expressed naïve views - 21% of them describing the process as "the scientific method" (p422). Most of the teachers viewed technology as applied science. The authors concluded that misconceptions about STS interactions were revealed in their study, a factor which could lead to science teachers limiting the integration of STS into science instruction.

In a similar study, Zoller and Ben-Chaim (1993: 77) examined the STS beliefs of 232 prospective and 57 practising social studies and science teachers in Israel. They found that differences existed in the STS profiles of the two groups. The implication was that appropriate teacher training programmes should be designed to achieve the objectives of STS education (p85).

In South Africa, Ayayee and McCarthy (1995: 102) investigated 47 pupils', 14 student teachers' and 20 teachers' views about the nature of science using 13 multiple-choice items from the VOSTS inventory. Pupils and teachers defined science as consisting of facts and processes. The majority of them presented the positivist view of one scientific method. The student teachers had a better understanding of some aspects of the nature of science, possibly due to their methodology course in the philosophy of science. The study supported findings in other countries that pupils and teachers have inadequate conceptions about the nature of science.

In the United States of America, Rubba et al. (1995: 355) used 16 multiple-choice items from the VOSTS pool of items to examine to what extent general education STS and physics courses helped college students build more realistic views about the interactions among STS. Two samples of 138 and 122 college students respectively were used to collect pretest and posttest data. A special scoring procedure was devised which allowed the use of inferential statistics. A three-category scoring scheme, viz. *realistic*, *has merit* and *naïve* was used. The authors reported that the students moved toward more realistic views on some items, but toward more naïve views on others, e.g. the definition of science. A possible explanation for this negative shift was the way in which the lectures were presented. They suggested that in future studies, interviews with the respondents should be conducted to find the reasons for a change in their views.

In 1991, Evans and Schibeci produced a modified version of the VOSTS instrument in Australia. It consisted of three subscales which described ***science*** (10 items), ***the scientific method*** (11 items), and ***how scientific knowledge changes*** (5 items). Students were asked to rate each of the 26 items - this was done to get a more "fine-grained" view of student views (p69). The questionnaire was administered to 434 year 10 Western Australian high school students. The majority of students saw science as a social enterprise, described the scientific method in a positivist way, and believed that scientific knowledge changes due to falsification. The authors concluded that, although no "correct" view of science exists, certain views are incompatible with modern epistemologies (p71). They also recommended that interviews be conducted with the students to get a more composite picture.

Parker and Rochford (1995: 68) used the modified VOSTS instrument to measure the perceptions of 82 young aspirant scientists and technologists and 391 mainstream secondary science students in Cape Town. The majority of mainstream students (74%) ascribed a social purpose to science, whereas 71% of the EXPO students expressed a more realistic view of science. Both sample groups expressed a "traditional" view of the scientific method. The authors found no significant differences between the views of the Cape Town mainstream students and those of the Australian students as reported by Evans and Schibeci (1991).

More recently, the writer Edwards et al. (1997: 2) found differences between the perceptions of 498 males and 499 females, from two high schools in Durban, on 15 of the 26 items comprising the modified VOSTS instrument. Both sub-groups expressed realistic views on some items, but naïve views on others, e.g. they did not distinguish between the roles of science and technology (p4). The majority of students viewed the scientific method in a "traditional" way, and a large proportion "did not know" about a more contemporary view of the scientific method. They also held the falsificationist position about scientific knowledge. The authors proposed that further studies be undertaken to explore the underlying reasons for the differences between the two groups.

Lederman (1992: 331) did an extensive review of the research related to students' and teachers' conceptions of the nature of science. A summary of some of the papers he reviewed and cited is presented below:

- Klopfer and Cooley (1961) developed the Test on Understanding Science (TOUS) in the USA. They concluded that high school students' understanding of the scientific enterprise and of scientists was inadequate. Many other researchers, using the TOUS instrument, corroborated their findings, e.g. Mackay (1971), Korth (1969) and Aikenhead (1972, 1973).
- Rubba (1977) developed the Nature of Scientific Knowledge Scale instrument. He found that 30% of high school students surveyed believed that scientific research reveals absolute truth and that scientific theories mature into laws.
- In a study using TOUS scores, Miller (1963) concluded that many teachers do not understand science as well as their students.

- Kimball (1968) used his own Nature of Science Scale (NOSS) to compare the understanding of the nature of science by American scientists and science teachers. He found no significant differences between the two groups' perceptions of the nature of science.
- Koulaidis and Ogborn (1989) described and compared beginning- and preservice-teachers' views about scientific knowledge in the USA. Their findings were consistent with previous research, i.e. teachers did not generally possess views which were consistent with a particular philosophical position.
- In assessing American preservice secondary teachers' conceptions of the nature of science, Aguirre, Haggerty and Linder (1990), found that most individuals believed science to be either a body of knowledge consisting of a collection of observations and explanations or of propositions that have been proven to be correct.

All the above findings are cited by Lederman (1992: 331-359).

Pomeroy (1993: 263) developed a 50-item survey "to explore the persistence of other more traditional beliefs about the nature of science". The respondents were 71 Alaskan scientists and 109 teachers. More scientists expressed stronger traditional views of science than secondary teachers, who in turn held stronger views than elementary teachers. The majority of teachers held more non-traditional views of science than scientists. The scientists also expressed more traditional views of science education than all the teachers grouped together. The author concluded that these different views of science may be further explored in interviews and observations with the respondents.

Palmquist and Finley (1997:595) determined 15 preservice science teachers' views of the nature of science, and they described the changes in those views that occurred during a teacher education programme at the University of Minnesota. An investigator-developed survey was used in conjunction with a follow-up interview after a science teaching methods sequence. They found that the teachers had a contemporary view of scientific theory, knowledge and the role of a scientist, and a traditional view of the scientific method. After the science teaching methods sequence, the number of contemporary views doubled and the number of mixed views decreased by more than half. The authors concluded that, although no direct instruction about the nature of science occurred, positive changes in teachers' views could take place when contemporary teaching strategies are employed.

Abd-el-Khalick et al. (1998:417) undertook a study in the USA to delineate the factors that mediated the translation of 14 preservice secondary science teachers' conceptions of the nature of science into instructional planning and classroom practice. The participants responded to an open-ended questionnaire before they commenced student teaching. During their student teaching, the lesson plans, classroom videotapes, portfolios, and the supervisors' weekly clinical observation notes of the teachers were scrutinised for explicit references to the nature of science. After student teaching, the teachers were interviewed to validate their responses to the questionnaire and to identify the factors or constraints that mediate the translation of their conceptions of the nature of science into their classroom teaching. The teachers were found to have adequate understandings of several important aspects of the nature of science, but explicit references to the nature of science were rare in their planning and instruction. The authors proposed that a possible approach might be to let the prospective teachers first develop their own understanding of the nature of science, and then to teach them how to transfer this during in-service training. Such an approach would allow the teachers to teach the nature of science in the realistic context of the secondary classroom (p433).

Tsai (1998: 473) administered a Chinese version of Pomeroy's (1993) questionnaire about the nature of science to 202 Taiwanese eighth graders. Twenty students were used in the final sample to analyse the interaction between their scientific epistemological beliefs and their learning orientations. A qualitative analysis by means of interviews revealed that those students who hold constructivist (non-traditional) views of science use a more active manner and adopt more meaningful strategies in learning science, whereas those students who hold empiricist (traditional) views adopt more rote-like strategies to enhance their understanding. The former are motivated by interest and curiosity, and the latter mainly by examination results. The author proposed that teacher education programmes should offer relevant courses to expound the constructivist philosophy; the science curriculum should focus on knowledge about science (not just scientific knowledge); and the way we teach can also play a role in the development of students' epistemological views about science (p486). However, these recommendations should be viewed with caution since only a small number (n = 20) of responses were used in the final analysis.

Ogunniyi (1999) and a team of researchers reported their findings on grades 7-9 pupils' levels of scientific and technological literacy in the Western Cape. The study was concerned with determining what knowledge, attitudes or views about S&T are held by approximately 6000 grades 7-9 pupils, drawn in a stratified manner from 60 primary and 40 secondary schools (p5). A total of 32 instruments were developed, and of particular interest is the instrument *My Idea about Science and Technology* which was used to determine teachers' and pupils' knowledge of S&T (p228). The instrument highlighted similarities and differences in their views. Most of the teachers (83%) and pupils (91%) agreed with the statement that "science shows the truth about nature". Both groups also appeared to hold the erroneous view that technologically developed appliances, such as televisions, radios and telephones, are the direct products of science. Ogunniyi concluded that their views were sometimes disparate and not in conformity with those held by practising scientists or engineers.

The review of the literature above has shown that items from the 114 VOSTS item pool have been used in many studies. In none of the studies were comparisons made between the perceptions of high school students and tertiary level students, such as college of education and technikon students. This study, using a modified version of the VOSTS instrument, compares not only these groups' perceptions of the nature of science, but also makes a comparison between two international student groups at the Year 10 level.

2.2 Theoretical Framework

The earlier view of the nature of science is that which was developed by Francis Bacon, the essence of which is that scientific studies start with an open-minded accumulation of data, followed by the development of a hypothesis to explain the data, and then followed by the testing of the hypothesis by means of key experiments (Ellington, 1981: 9). If the hypothesis is verified repeatedly and consistently, it becomes scientific law and is constituted as part of the body of knowledge. The process of scientific induction (when the hypothesis is derived from individual observations) was regarded as that which distinguished science from non-science. However, David Hume questioned the validity of this view of the scientific method since he claimed that no general statement can be derived from a finite number of observations (Ellington, 1981: 10). Hodson (1982:112) has argued that the inductive method is the traditional view of scientific method.

Karl Popper contended that a scientific law can be disproved (falsified) by a single properly-authenticated observation that does not fit in with its predictions (Ellington, 1981: 10). Thus, scientific laws should be tested by trying to prove them wrong; when this happens they lose their status as certain knowledge. The Popperian view of the nature of science contradicts the Baconian view in almost every respect, and it can be useful in the sense that science can still advance when laws are subjected to rigorous testing which may result in the law being invalidated. According to Popper, science proceeds by conjectures and refutations until it arrives at a theory which satisfactorily explains the evidence (Hodson, 1982: 113). His method is also referred to as the hypothetico-deductive method.

Thomas Kuhn developed the concept of a paradigm, the basic, generally-accepted theoretical model that underlies a particular branch or sub-branch of science (Ellington, 1981: 19). According to Kuhn, science develops in revolutionary spurts (scientific revolutions) interspersed with periods of consolidation and expansion (normal science). There is a period when contending schools of thought are vying for supremacy of its ideas, until one becomes the accepted paradigm. Classical examples of paradigm shifts are: the Copernican revolution in astronomy, the Darwinian revolution in biology, and the Einsteinian revolution in physics.

Pomeroy (1993: 262) defined logicoempiricism as the belief that science is strictly bound by rules of inductive logic and that a true knowledge of nature can only be determined and confirmed by observation and experimentation. This traditional, Baconian belief precedes the Kuhnian era. However, non-traditionalists recognise the richness and variety of experience that prompt valid scientific discovery, e.g. dream, intuition, play, etc. all form part of the scientific method in the contemporary era.

Tsai (1998: 474-475) distinguished between empiricist and constructivist views of science as follows:

Table 2.1 Empiricist and constructivist views of science, after Tsai (1998: 474-475).

Empiricist	**Constructivist**
Scientific knowledge is unproblematic and it provides right answers.	Scientific knowledge is constructed (or invented) by scientists.
Scientific knowledge is discovered by the objective data gathered from observing and experimenting or from an universal scientific method.	Scientific knowledge development experiences a series of revolutions or paradigm shifts.
Scientific knowledge is additive and bottom-up, and evidence accumulated carefully will result in infallible knowledge.	Scientific knowledge is tentative.

Many of these contrasting views match some of the items on the modified VOSTS instrument. For example, item 3B reads, "scientific knowledge *changes because the old knowledge is reinterpreted in the light of new discoveries - scientific facts can change"*, whereas item 3E states that *"new knowledge is added onto old knowledge"*.

Palmquist and Finley (1997: 611-613) contrasted the traditional and contemporary models of the nature of science. Only the roles of theory, scientific method and scientific knowledge are outlined below:

Table 2.2 Traditional and contemporary models of the nature of science, after Palmquist and Finley (1997: 611-613).

	Traditional Model	Contemporary Model
Theory	Theories are based directly on observation.	Observations are theory-laden.
	New theories are improvements over old theories.	Theories are the inventions of scientists.
	An entire theory is falsified if subject to a single contradictory fact.	The occurrence of a contradictory fact does not necessarily compel the abandonment of a theory.
	A theory is a hypothesis that has been proven to be correct.	Theories are tools used to describe, explain, and predict scientific phenomena.
	Old theories are of no use to scientists.	Theories fit within certain paradigms.
Scientific Method	Science relies on precise control of experiments for proof.	Methods used by scientists depend on circumstances.
	The use of the traditional scientific method is necessary to discover and validate theories.	Scientists are not compelled to use the traditional scientific method.
	There is a single method for doing science.	There is no single scientific method.
	The scientific method is a step-by-step process.	Knowledge can be gained by means other than the scientific method.
	The method must be planned out in advance of the inquiry.	The traditional scientific method is simply one possible guide for inquiry.
	When a scientist uses the traditional scientific method correctly, the results are true without doubt.	Scientists can adjust their method of inquiry in the middle of an investigation and still obtain valid results.
Scientific Knowledge	Scientific knowledge corresponds directly to reality.	The progression of scientific knowledge is not continuous.
	Scientific knowledge increases by accretion from observations.	Scientific knowledge is tentative.
	Scientific knowledge progresses by an accumulation of observations.	Scientific knowledge is created and validated by common acceptance within the scientific community.
	Scientific knowledge is proven or disproven owing to the direct influence of observations.	Scientists create knowledge based on prior knowledge, observation, and logic.
	Scientific knowledge is unchanging.	The tentativeness of knowledge is related to how much people work on it.
	Scientific data must not be interpreted by the scientist.	The truth is defined as an accurate description of nature.

The items on the three subscales of the modified VOSTS instrument also match some of the items as contrasted in the table above. Item 21 states that the scientific method is *"a logical and widely accepted approach to solving problems"* - which matches the traditional model above.

The draft document on the Learning Area of the Natural Sciences (Department of Education, 1997: 53) also outlines specific outcomes which can be construed to be either "traditional" or "contemporary". For example, learners must be able to: identify, select, and critically evaluate information; investigate natural phenomena using scientific process skills such as analysing, predicting, interpreting, etc.; and recognise the tentative nature of science. Another specific outcome is that the learner must be able to participate knowledgeably in democratic decision-making processes on social and environmental issues relating to the Natural Sciences. Therefore this present study has the potential to highlight students' perceptions of many of these stated outcomes, thus helping to complete gaps in the currently available research literature by gathering more school-based evidence in support of the recent government decisions on the proposed format of Curriculum 2005.

2.3 Chapter Summary

In this chapter an extensive review of the literature has shown the emergence and divergence of two broad schools of thought with regard to the nature of science, i.e. "traditional" and "contemporary". A review and critique of the related research findings in which the VOSTS and the modified VOSTS instruments were used, has been presented. Then, some general research findings on the nature of science were outlined. A synopsis of the theoretical framework to be used in the interpretation of the empirical findings of this study was presented; and finally it was shown how the present investigation will close some of the gaps in the current literature by supplying school-based, college-based and technikon-based evidence in support of the adoption, by the government, of the content and format of the unfolding plan for Curriculum 2005.

In the following chapter the research method, the samples, the measuring instrument, and the data collection method used in this particular study are described in detail.

CHAPTER 3

RESEARCH METHOD

"Method" refers to the techniques and procedures used in the process of data-gathering (Cohen and Manion, 1989: 41). The collected data is then used as a basis for analysis and interpretation. In descriptive research one describes and interprets what is, i.e. attitudes, beliefs, points of view, etc. - the most common descriptive method being the survey (Cohen and Manion, 1989: 97).

In this chapter the descriptive survey research method is outlined, the samples are located and described, the reliability and validity of the measuring instrument is discussed and the hypotheses are stated. Finally, the data collection procedure is outlined and the treatment of the data is delineated in detail.

3.1 The Descriptive Survey

The research method employed in this study is the descriptive survey. A survey is an attempt to obtain measurements from a sample of individuals selected from a predefined finite population in their natural setting (Walker and Burnhill, 1988: 101). It can be used to make policy, or plan and evaluate programmes, and conduct research when the information must come directly from people (Fink and Kosecoff, 1985: 15). The descriptive survey relies upon observation for the acquisition of the data which must then be organised and presented systematically so that valid and accurate conclusions can be drawn from them (Leedy, 1993: 187).

There are two types of survey designs, viz. cross-sectional and longitudinal. The cross-sectional study was used because measurements are obtained at a particular time for the purpose of describing situations rather than establish causal patterns (Walker and Burnhill, 1988: 101). It is less expensive than cohort studies because it ensures the co-operation of the respondents on a one-off basis, and more subjects can be included (Cohen and Manion, 1989: 73). A cross-sectional design that is carefully planned also gives a variety of ways for analysing and presenting the survey data (Fink and Kosecoff, 1985: 67).

The questionnaire serves as an ideal tool to acquire the data which lies within the perceptions of individuals. A self-completion questionnaire was administered since it allows for easy supervision of students and student teachers who are a readily accessible population. All the items are "closed", which forces the respondents to choose from preselected alternatives - these have proven themselves to be more efficient and reliable, i.e. easy to use, score and code since everyone responds to the same options (Fink and Kosecoff, 1985: 26). The modified VOSTS questionnaire makes use of a rating scale with an ordered series of categories. The scale can be considered an ordinal measure, although some may take it to be an interval measure (Fink and Kosecoff, 1985: 34).

The sampling procedure used in this study is a non-probability sampling method, viz. convenience or accidental sampling. It has been used because the groups of students and student teachers were willing, interested and readily available groups. The method is also adequate since it is not intended to generalise the findings of this study beyond the samples in question - there is no guarantee that each element in the population will be represented in the sample (Leedy, 1993: 200).

The questionnaire was also administered during formally supervised lesson/lecture time. An intact response rate of about 98% was obtained with only a few of the forms being incomplete.

3.2 Description and Location of the Samples

The four local samples were drawn from two suburban high schools, one college of education, and a technikon in the Western Cape. The Australian sample, used for comparative purposes, is taken from the study of Evans and Schibeci (1991) in which 434 Year 10 high school students in three Perth metropolitan high schools were surveyed.

The two suburban high schools in Cape Town are both English medium schools which used to be administered by the former House of Representatives (HoR). Under the auspices of the HoR both schools were considered in the top three nationally. The student population at both schools was drawn from residential areas across the Cape Peninsula, rather than the immediate area in which the school is located. Many of the students came from a middle-class background, but some also came from the poorer areas in the Peninsula.

Sample 1 (n = 320) comprised standard eight (grade 10) students, age range 15 to 16, at the two suburban high schools. The sample was made up of 182 males and 138 females, all of whom took Biology or Physical Science as natural science subjects.

Sample 2 (n = 340) comprised standard ten (grade 12) students, age range 17 to 18, at the two suburban high schools. The sample was made up of 154 males and 186 females, all of whom took Biology or Physical Science as natural science subjects.

Sample 3 (n = 108) comprised first-year electrical engineering students, age range 18 to 19, at a technikon in the Cape Peninsula. The technikon draws its student population mostly from township areas - many of the students matriculated under the auspices of the former Department of Education and Training. The sample was made up of 97 males and 11 females. The preponderence of males in this discipline is self-evident.

Sample 4 (n = 55) comprised first-year college of education students, age range 18 to 19, at a teacher-training college in Cape Town. The college has subsequently merged with another college in Cape Town. Most of the students matriculated under the auspices of the HoR. The sample was made up of 13 males and 42 females, all of whom took Science and Mathematics as their method subjects.

Sample 5 comprised the groups of Australian students in Perth (n = 434) described above. A breakdown of the males and females is not available. Howie and Hughes (1998: 20) reported that Australian students had an average mathematics and science literacy score of 525 compared with the South African students' score of 352 in the Third International Mathematics and Science Study. They also indicated that a high proportion of Australian students use computers daily whereas 81% of South African students said that they rarely or never used a computer. As a first world country, Australia has a well developed science and technological infrastructure.

3.3 Reliability of the modified VOSTS instrument

Reliability coefficients are correlation coefficients between two sets of scores. They determine the amount of variance in the test scores which may be attributed to the true differences among individuals (Burns and Dobson, 1983:337).

Many tests require no right or wrong answer, for example, attitude or personality scales. The responses are spread across a continuum. Cronbach developed a reliability measure which is used to estimate the internal consistency of such scales. This general reliability estimate he called coefficient alpha (α) (Kaplan, 1987:252).

$$\alpha = \left(\frac{N}{N-1}\right)\left(\frac{S^2 - \Sigma S_i^2}{S^2}\right)$$

where N = the number of items on the test

S^2 = the variance of the total test scores

ΣS_i^2 = the sum of the individual item variances.

Classical theory makes the following assumptions:

1. the items measure a single factor or trait,
2. the item-intercorrelations are equal,
3. the items have equal variances,
4. the items have equal difficulties.

Cronbach's α assumes that at least the first three assumptions are valid (Bartram 1990:71).

Computation of Cronbach's α using the item variances and total scale score variance on the modified VOSTS scales:

The raw scores of sample 4 have been used to calculate α (See Appendix D):

$$N = 26 \text{ items}; \; S^2 = 72.02; \; \Sigma S_i^2 = 18.17$$

$$\alpha = \frac{26}{25} \frac{(72.02 - 18.17)}{(72.02)}$$
$$= (1.04)(0.748)$$

$$\alpha = 0.778$$

This measure of approximately 0.78 means that the internal consistency or reliability of the modified VOSTS instrument is quite high. Too high a level of consistency could indicate that the questions are possibly repetitive. However, the actual value of α must be interpreted with caution since the assumption of equal item variances is not strictly true for the data used in the above calculation.

3.4 Validity

Validity deals with the effectiveness of the measuring instrument - does it measure what it is supposed to measure? There are several types of validity: for example, predictive, concurrent, face, criterion, content, construct, internal, and external validity (Leedy, 1993: 41).

Aikenhead and Ryan (1992: 487-488) have argued for the external reconceptualisation of validity which goes beyond technical concerns and explores the meaning of the term within the reseach paradigm. The VOSTS items were developed by gathering empirical data about how students *actually* respond to an item. Thus, it is assumed that the VOSTS items possess an inherent content validity as described on page 2 of Chapter 1.

3.5 Hypotheses

The following null hypotheses are tested in this study:

Null Hypothesis 1 (Year 10 vs. year 12 students)

That no statistically significant differences exist between the responses of 320 standard 8 science students and the responses of 340 standard 10 science students in Cape Town to the importance of 26 statements on the modified VOSTS measure of the perceptions of the nature of science, scientific method and knowledge.

Null Hypothesis 2 (Cape Town vs. Perth students)

That no statistically significant differences exist between the responses of 320 standard 8 science students in Cape Town and the responses of 434 standard 8 (Year 10) science students in Perth to the importance of 26 statements on the modified VOSTS measure of the perceptions of the nature of science, scientific method and knowledge.

Null Hypothesis 3 (Year 12 vs. engineering students)

That no statistically significant differences exist between the responses of 340 final year high school science students in Cape Town and the responses of 108 electrical engineering students in Cape Town to the importance of 26 statements on the modified

VOSTS measure of the perceptions of the nature of science, scientific method and knowledge.

Null Hypothesis 4 (Year 12 vs. college of education students)

That no statistically significant differences exist between the responses of 340 final year high school science students in Cape Town and the responses of 55 first year college of education science students in Cape Town to the importance of 26 statements on the modified VOSTS measure of the perceptions of the nature of science, scientific method and knowledge.

3.6 Data collection procedure

Before the self-completion questionnaire was administered to the students at the two high schools, college of education and technikon respectively, verbal permission was obtained from the relevant heads or heads of department at these institutions.

The questionnaires were given to the student respondents at the start of a science lesson or lecture in electrical engineering. This ensured that the whole class could participate and complete the questionnaire in the allotted time of 20 minutes. The students were instructed to complete the forms and respond to all the statements on the three scales. The completed questionnaires were collected by the researcher with the assistance of the science teacher or lecturer at the particular institution. This technique produced a high response rate compared with the results of mailed questionnaires where the respondents may choose not to reply. As indicated above, the completion of only a few forms was inadequate, and the rest were ready for data capturing.

3.7 The treatment of the data

The modified VOSTS instrument uses a four-category rating scale which is coded 4, 3, 2 and 1 to represent "major part", "minor part", "no part" and "I don't know" respectively. This made it possible for inferential statistical procedures to be used once all the data had been captured on the computer.

The data for each sample group were entered separately in a spreadsheet programme and saved so that it may be imported into a statistical analysis programme. A statistical analysis was done to produce frequencies of responses in each of the four categories. These frequencies were entered for any comparison to be made between the various sample groups. As indicated in Chapter 1, two non-parametric statistical tests were employed to make comparisons between the groups, viz. the Chi-square (χ^2) test and the Mann-Whitney U-test. The chi-square distribution is not accurate if the frequencies are less than five (Kaplan, 1987:267). Thus, the Mann-Whitney U-test was used when this was the case. In both instances the assumption has been that the sample populations are not normally distributed.

Chi-square (χ^2) Test: This is a non-parametric statistical test which is used to evaluate frequency data that are at the nominal level (Kaplan, 1987:266).

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where O = observed frequency and
E = expected frequency.

This statistic would take long to compute by hand for all the data available. The statistical analysis by computer only requires the frequencies for each of the four categories for the the two sample groups being compared. A contingency table is generated, the χ^2 statistic is calculated and the level of significance is given as well. See Appendix E.

Mann-Whitney U-test: This is considered to be the counterpart of the t-test in parametric measurements (Leedy, 1993: 284). The data from two independent samples is combined and ranked. Then the sum of the ranks is obtained for each group and the average ranks are compared to test the difference between the two population distributions. The null hypothesis will be rejected if there is no significant overlap between the population distributions (Kaplan, 1987: 285). In the computation of the Mann-Whitney U-test a Z-score is calculated. The level of significance is also given. See Appendix E.

3.8 Chapter summary

In this chapter the research method, the sample groups and the setting of the survey have been described in detail. The reliability and validity of the measuring instrument was discussed, the hypotheses were stated and the data-gathering procedure was outlined. The proposed treatment of the data was presented, and included a description of the statistical tests which are to be used. The results and findings of this study now follow in Chapter 4.

CHAPTER 4

RESULTS AND FINDINGS

In this chapter the results of the study are summarised, tabulated and, where appropriate, graphically illustrated. The findings are presented in order of the hypotheses 1 to 4 as set out in the previous chapter. A brief analysis of the emerging trends is introduced, but a more detailed discussion follows in Chapter 5.

4.1 Hypothesis Testing

- Hypothesis 1 (Std. 8 vs. Std. 10 students in Cape Town in 1995)

The **null hypothesis,** that no statistically significant differences exist between the responses of 320 standard 8 science students and the responses of 340 standard 10 science students to the importance of 26 statements on the modified VOSTS measure, **is rejected**. Responses to seven of the 26 items yield statistically significant differences between the perceptions of the two groups. Table 4.1 on page 46 gives the χ^2-test statistics obtained using the frequencies of responses for each item.

The greatest significant difference occurs on item 1l, i.e. the perceived importance of **science** as *a body of fundamental ideas, such as principles, laws and theories* by the older sample of students. On 19 of the 26 modified VOSTS items the response patterns of the standard 8 and standard 10 groups are comparable or similar. This suggests that the teaching of a further two years of science to standard 8 pupils might have done little to change stable perceptions of these 19 aspects of the nature of science, all other external factors being equal. It is especially noteworthy that on items 1B and 2I there is close agreement, i.e. **science is** *finding cures for diseases and helping the environment* and, **the scientific method is** *a logical and widely accepted approach to solving problems*. Figure 4.1 illustrates this graphically.

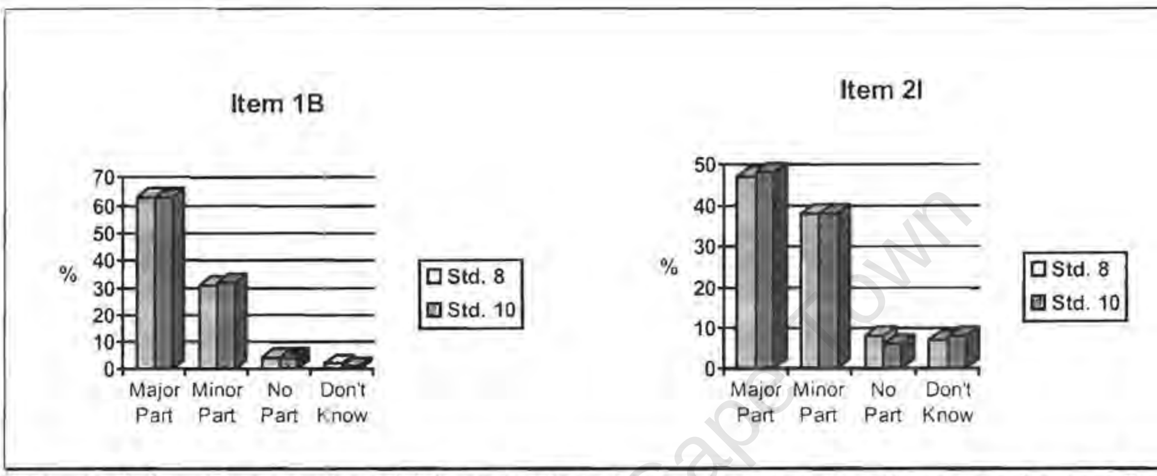

Figure 4.1 : Bar graphs which show the close agreement patterns on items 1B and 2I of the modified VOSTS instrument for Std. 8 students (n=320) and Std. 10 students (n=340) in Cape Town in 1995.

Table 4.1: χ^2 - test statistics and levels of significant differences between the responses of Std. 8 students (n=320) and Std. 10 students (n=340) in Cape Town in 1995

Item Number	χ^2-test statistic	Level of significance
1A	1.60	
1B	0.50	
1C	5.12	
1D	4.15	
1E	8.25	*
1F	5.62	
1G	6.26	
1H	10.49	*
1I	19.58	***
1J	1.64	
2A	9.31	*
2B	3.55	
2C	15.27	**
2D	2.86	
2E	4.85	
2F	1.65	
2G	7.33	
2H	3.16	
2I	1.12	
2J	3.67	
2K	9.00	*
3A	6.05	
3B	4.22	
3C	1.80	
3D	12.25	**
3E	3.61	

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

Table 4.2 : Comparative percentage responses of Std. 8 students (n=320) and Std. 10 students (n=340) in Cape Town in 1995

Item Number	Major Part		Minor Part		No Part		I Don't Know	
	Std. 8	Std.10	Std. 8	Std.10	Std. 8	Std.10	Std. 8	Std.10
1A	48	45	42	42	7	10	3	3
1B	63	63	31	32	4	4	2	1
1C	63	70	33	26	2	3	2	1
1D	48	49	39	43	7	5	6	3
1E	35	40	47	46	12	12	6	2
1F	72	76	20	20	4	3	4	1
1G	68	67	26	27	2	4	4	2
1H	51	49	32	38	6	8	11	5
1I	52	63	32	31	5	3	11	3
1J	62	66	28	26	7	5	3	3
2A	42	51	31	30	3	4	24	15
2B	71	77	22	16	2	2	5	5
2C	35	41	26	32	15	14	24	13
2D	66	69	21	21	2	3	11	7
2E	76	79	15	15	4	1	5	5
2F	58	59	24	25	5	6	13	10
2G	61	70	25	18	3	3	11	8
2H	75	77	18	16	2	3	5	4
2I	47	48	38	38	8	6	7	8
2J	46	42	30	37	13	12	11	9
2K	10	9	14	21	29	32	47	38
3A	66	71	19	20	3	2	12	7
3B	59	65	29	27	5	4	7	4
3C	39	38	44	42	10	14	7	6
3D	31	36	35	35	10	15	24	14
3E	38	39	35	29	12	16	15	16

Additional Findings

The following findings emerge from an analysis of the comparative percentage responses in Table 4.2 :

- On Scale One both groups gave the highest importance to item 1F as a description of science, i.e. **science is** *exploring the unknown and discovering something new about our world and universe;*

- On Scale Two both groups gave the highest importance to item 2E as a description of the scientific method, i.e. **the scientific method is** *testing and retesting, proving something true or false in a valid way;*
- On Scale Three both groups gave the highest importance to item 3A as a description of how scientific knowledge changes, i.e. **scientific knowledge** changes *because new scientists disprove the theories or discoveries of old scientists.*

The high prioritisation of items 1F, 2E and 3A is graphically depicted in figure 4.2.

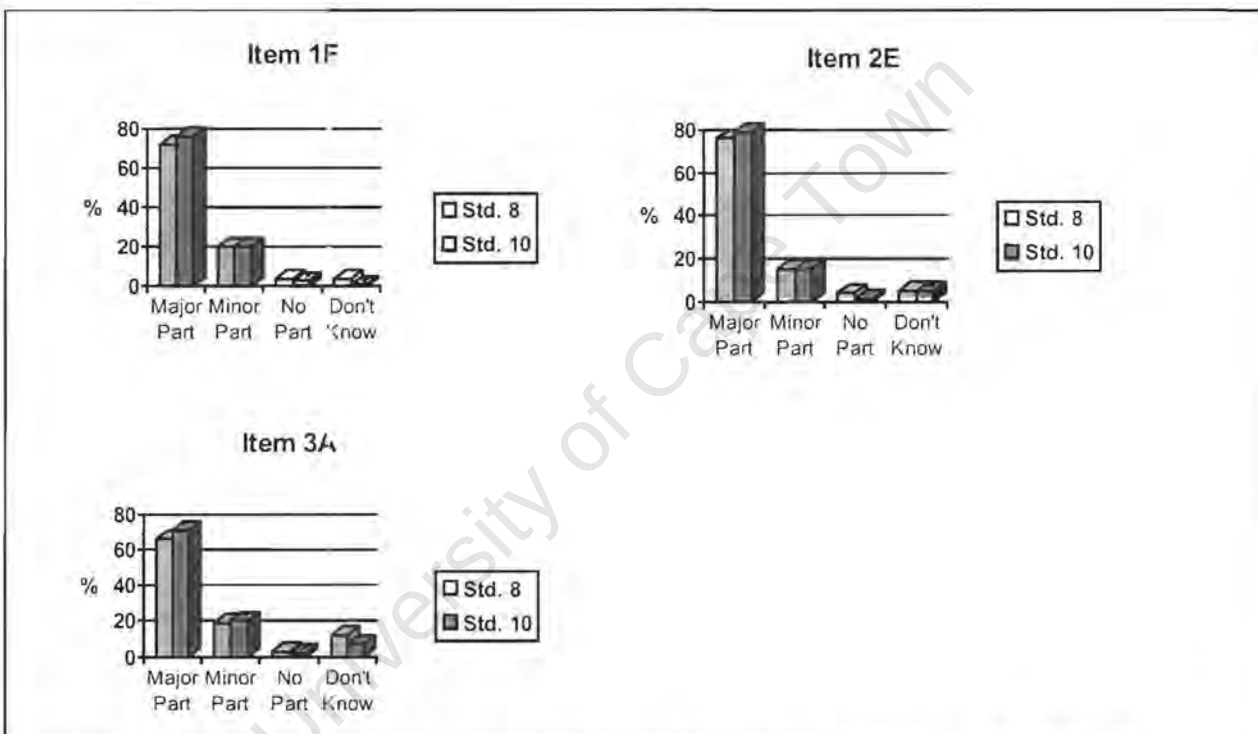

Figure 4.2 : Bar graphs which show the high prioritisation of items 1F, 2E and 3A on the modified VOSTS instrument for Std. 8 students (n=320) and Std. 10 students (n=340) in Cape Town in 1995.

The high percentage of "I don't know" responses on item 2K is unusual, but not inconsistent with the response patterns which emerged in this study (see Tables 4.4, 4.6 and 4.8 on pages 51 - 58). This may be attributed to the wording of the item, or to the non-exposition of the view that "there really is no such thing as the scientific method" by the teachers of these two groups.

- <u>Hypothesis 2</u> (Std. 8 - Year 10 - students at two Cape Town suburban high schools in 1995 vs. Year 10 students at three Perth metropolitan high schools in 1991)

The **null hypothesis**, that no statistically significant differences exist between the responses of 320 standard 8 (Year 10) science students in Cape Town and the responses of 434 standard 8 (Year 10) science students in Perth to the importance of 26 statements on the modified VOSTS measure, **is rejected**. Twenty of the 26 items yield statistically significant differences between the two groups. The two geographically remote samples therefore hold appreciably discrepant views on the instrument as a whole. Table 4.3 on page 50 gives the χ^2-test statistics obtained using the frequencies of responses for each item. Fourteen of the items yield highly significant differences at the p=0.001 level.

The most significant difference occurs on item 2H, favoured by the Cape Town sample, i.e. **the scientific method** *is being accurate and not making errors*. The comparative percentage responses in Table 4.4 show that in 1995 75% of the Std. 8 sample believed that this plays a major part, compared with only 51% of their Australian counterparts in 1991. However, the two groups agree closely on item 1F, i.e. **science is** *exploring the unknown and discovering something new about our world and universe*. Again it is noteworthy that the agreement on item 2K is largely due to the high percentage of "I don't know" responses. The different distributions of the response categories to the two items are plotted in figure 4.3 on page 50 below.

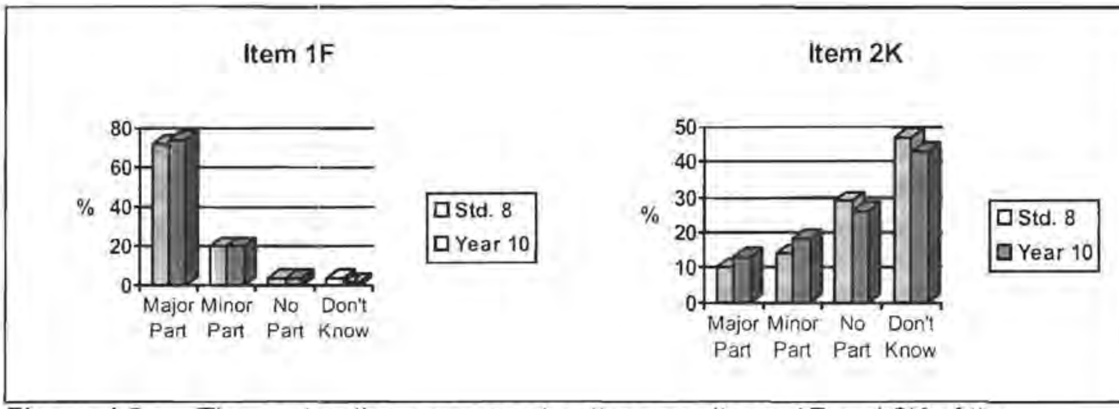

Figure 4.3 : The contrasting agreement patterns on items 1F and 2K of the modified VOSTS instrument for Std. 8 (Year 10) students (n=320) in Cape Town in 1995 and Year 10 students (n=434) in Perth in 1991.

Table 4.3: χ^2 - test statistics and levels of significant differences between the responses of Std. 8 (Year 10) students (n=320) at two Cape Town suburban high schools in 1995 and Year 10 students (n=434) at three Perth metropolitan high schools in 1991.

Item Number	χ^2-test statistic	Level of significance
1A	15.29	**
1B	36.95	***
1C	25.50	***
1D	9.86	*
1E	47.01	***
1F	2.24	
1G	30.71	***
1H	5.87	
1I	14.04	**
1J	13.21	**
2A	21.10	***
2B	20.40	***
2C	11.96	**
2D	31.12	***
2E	16.54	***
2F	16.27	***
2G	23.21	***
2H	53.23	***
2I	16.82	***
2J	34.69	***
2K	3.86	
3A	7.25	
3B	22.77	***
3C	11.95	**
3D	5.13	
3E	4.88	

* P < 0.05; ** P < 0.01; *** P < 0.001

Table 4.4: Comparative percentage responses of Std. 8 (Year 10) students (n=320) at two Cape Town suburban high schools in 1995 and Year 10 students (n=434) at three Perth metropolitan high schools in 1991. #

Item Number	Major Part		Minor Part		No Part		I Don't Know	
	Std. 8	Year10	Std. 8	Year10	Std. 8	Year10	Std. 8	Year10
1A	48	58	42	34	7	3	3	5
1B	63	81	31	14	4	2	2	3
1C	63	44	33	50	2	3	2	3
1D	48	40	39	50	7	4	6	6
1E	35	17	47	45	12	27	6	11
1F	72	74	20	20	4	4	4	2
1G	68	48	26	42	2	4	4	6
1H	51	43	32	37	6	6	11	14
1I	52	40	32	38	5	10	11	12
1J	62	53	28	34	7	5	3	8
2A	42	32	31	42	3	8	24	18
2B	71	58	22	34	2	5	5	3
2C	35	38	26	38	15	9	24	15
2D	66	49	21	36	2	6	11	9
2E	76	62	15	25	4	6	5	7
2F	58	47	24	36	5	7	13	10
2G	61	45	25	35	3	8	11	12
2H	75	51	18	30	2	10	5	9
2I	47	34	38	44	8	8	7	14
2J	46	26	30	42	13	14	11	18
2K	10	13	14	18	29	26	47	43
3A	66	56	19	25	3	4	12	15
3B	59	42	29	37	5	9	7	12
3C	39	34	44	39	10	13	7	14
3D	31	24	35	38	10	12	24	26
3E	38	33	35	33	12	14	15	20

After Evans and Schibeci (1991: 69-70).

Additional Findings

An analysis of the comparative percentage responses in Table 4.4 reveals that:

- On Scale One 72% of the Std. 8 students gave the highest importance to item 1F, i.e. **science is** *exploring the unknown and discovering something new about our world and universe*, whereas 81% of their Australian counterparts instead highly prioritised item 1B, **science is** *finding cures for diseases and helping the environment*;

- On Scale Two both groups gave the highest importance to item 2E as a description of the scientific method, i.e. **the scientific method is** *testing and retesting, proving something true or false in a valid way;*

- On Scale Three both groups gave the highest priority to item 3A as a description of how scientific knowledge changes, i.e. **scientific knowledge** changes *because new scientists disprove the theories or discoveries of old scientists.*

These findings are similar to the findings recorded for the Std. 8 and Std. 10 groups, except that the Year 10 group gave the second highest importance (74%) to item 1F on Scale One.

- Hypothesis 3 (Std. 10 students in Cape Town vs. Electrical Engineering students in Cape Town in 1995)

The **null hypothesis**, that no statistically significant differences exist between the responses of 340 final year high school science students in Cape Town and the responses of 108 electrical engineering students in Cape Town to the importance of 26 statements on the modified VOSTS measure, **is rejected**. Ten of the 26 items yield statistically significant differences between the two groups. Table 4.5 on page 54 gives the Z-test statistics obtained using the Mann-Whitney U-test as outlined in Chapter 3.

The greatest significant difference occurs on item 2H, which is more favoured by the standard 10 sample, i.e. **the scientific method** *is being accurate and not making errors*. There is close agreement on item 1I, i.e. **science** ***is*** *a body of fundamental ideas, such as principles, laws and theories*. Figure 4.4 graphically illustrates the findings recorded for item 1I.

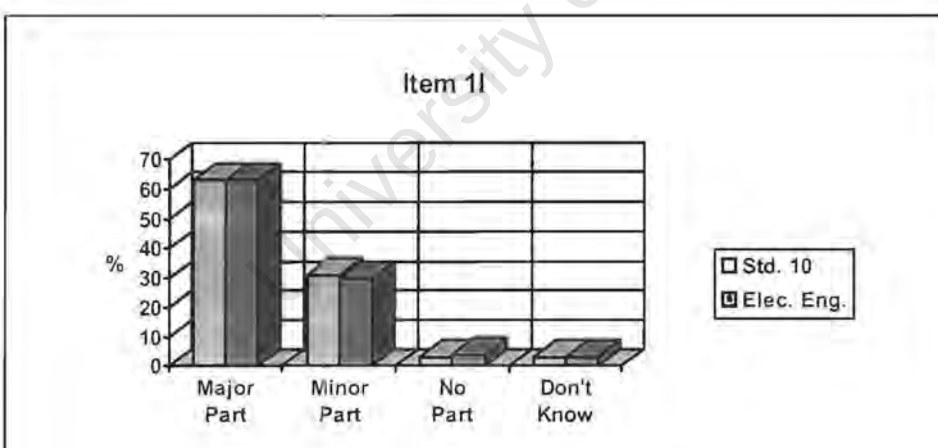

Figure 4.4: Plot showing the close agreement of response patterns on item 1I of the modified VOSTS instrument for Std. 10 students (n=340) and Electrical Engineering students (n=108) in Cape Town in 1995.

Table 4.5: Z - test statistics and levels of significant differences between the responses of Std. 10 students (n=340) and Electrical Engineering students (n=108) in Cape Town in 1995

Item Number	Z-test statistic	Level of significance
1A	5.86	***
1B	0.41	
1C	-1.88	
1D	-2.38	*
1E	-4.10	***
1F	0.99	
1G	-1.61	
1H	-1.28	
1I	0.03	
1J	-1.45	
2A	0.53	
2B	-2.42	*
2C	-1.64	
2D	-1.99	*
2E	-0.25	
2F	1.73	
2G	-4.88	***
2H	-7.54	***
2I	1.09	
2J	-0.49	
2K	0.80	
3A	-1.36	
3B	-2.51	*
3C	-3.21	**
3D	0.36	
3E	2.72	**

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

Table 4.6: Comparative percentage responses of Std. 10 students (n=340) and Electrical Engineering students (n=108) in Cape Town in 1995

Item Number	Major Part		Minor Part		No Part		I Don't Know	
	Std.10	Electr. Eng.	Std.10	Electr. Eng.	Std.10	Electr. Eng.	Std.10	Electr. Eng.
1A	45	77	42	20	10	1	3	2
1B	63	66	32	29	4	4	1	1
1C	70	59	26	34	3	6	1	1
1D	49	40	43	43	5	10	3	7
1E	40	29	46	32	12	31	2	8
1F	76	81	20	12	3	6	1	1
1G	67	59	27	32	4	7	2	2
1H	49	44	38	40	8	9	5	7
1I	63	63	31	30	3	4	3	3
1J	66	57	26	34	5	7	3	2
2A	51	50	30	36	4	7	15	7
2B	77	65	16	25	2	8	5	2
2C	41	32	32	32	14	27	13	9
2D	69	58	21	26	3	9	7	7
2E	79	78	15	17	1	4	5	1
2F	59	68	25	23	6	4	10	5
2G	70	41	18	41	3	14	8	4
2H	77	38	16	41	3	17	4	4
2I	48	52	38	37	6	7	8	4
2J	42	40	37	35	12	18	9	7
2K	9	11	21	14	32	48	38	27
3A	71	63	20	26	2	7	7	4
3B	65	52	27	35	4	9	4	4
3C	38	25	42	40	14	31	6	4
3D	36	35	35	38	15	17	14	10
3E	39	49	29	31	16	17	16	3

It is noteworthy that both groups again viewed items 1F, 2E and 3A as being of the highest importance on Scales One, Two and Three respectively. Item 2K also elicited a large proportion of "I don't know" responses.

- <u>Hypothesis 4</u> (Std. 10 students in Cape Town vs. 1st year students at a College of Education in Cape Town in 1995)

The **null hypothesis**, that no statistically significant differences exist between the responses of 340 final year high school science students in Cape Town and the responses of 55 first year college of education science students in Cape Town to the importance of 26 statements on the modified VOSTS measure, **is rejected**. Nine of the 26 items yield statistically significant differences between the two groups. The two groups do not have widely disparate perceptions of the nature of science on 17 of the items. Table 4.7 on page 57 gives the Z-test statistics obtained using the Mann-Whitney U-test.

The greatest significant difference between the responses occurs on item 2H, more favoured by the standard 10 sample, i.e. **the scientific method** *is being accurate and not making errors.* Item 3C also yields a highly significant difference, more favoured by the standard 10 sample, i.e. **scientific knowledge** *changes because the earth's physical environment changes and this affects the outcome of investigations.*

Table 4.7: Z - test statistics and levels of significant differences between the responses of Std. 10 students (n=340) in Cape Town and 1st year College of Education students (n=55) in Cape Town in 1995

Item Number	Z-test statistic	Level of significance
1A	3.04	**
1B	2.20	*
1C	-0.62	
1D	0.07	
1E	-2.89	**
1F	1.05	
1G	-0.10	
1H	0.37	
1I	-1.57	
1J	-0.99	
2A	1.63	
2B	-0.95	
2C	-0.51	
2D	-2.30	*
2E	0.24	
2F	0.52	
2G	0.10	
2H	-4.02	***
2I	0.05	
2J	2.86	**
2K	2.83	**
3A	0.46	
3B	-0.56	
3C	3.38	***
3D	1.52	
3E	2.47	*

* P < 0.05

** P < 0.01

*** P < 0.001

Table 4.8: Comparative percentage responses of Std. 10 students (n=340) in Cape Town and 1st year College of Education students (n=55) in Cape Town in 1995

Item Number	Major Part		Minor Part		No Part		I Don't Know	
	Std.10	College of Edu	Std.10	College of Edu	Std.10	College of Edu	Std.10	College of Edu
1A	45	67	42	26	10	7	3	0
1B	63	78	32	20	4	2	1	0
1C	70	66	26	27	3	5	1	2
1D	49	55	43	29	5	11	3	5
1E	40	25	46	44	12	24	2	7
1F	76	84	20	9	3	5	1	2
1G	67	67	27	26	4	5	2	2
1H	49	54	38	29	8	13	5	4
1I	63	53	31	35	3	7	3	5
1J	66	62	26	20	5	14	3	4
2A	51	58	30	34	4	4	15	4
2B	77	71	16	20	2	7	5	2
2C	41	35	32	38	14	16	13	11
2D	69	54	21	26	3	4	7	16
2E	79	80	15	7	1	6	5	7
2F	59	64	25	20	6	9	10	7
2G	70	69	18	22	3	9	8	0
2H	77	53	16	26	3	16	4	5
2I	48	49	38	33	6	9	8	9
2J	42	62	37	27	12	9	9	2
2K	9	31	21	15	32	29	38	25
3A	71	74	20	13	2	9	7	4
3B	65	60	27	34	4	2	4	4
3C	38	0	42	64	14	25	6	11
3D	36	45	35	35	15	7	14	13
3E	39	60	29	18	16	9	16	13

It is noteworthy that there is close agreement on items 2I, 1G and 2G. The two groups gave the highest importance to items 1F, 2E and 3A on the three scales respectively, while item 2K again had a large percentage of "I don't know" responses.

4.2 Chapter Summary

Four null hypotheses have been tested in this study. All were rejected. Of the groups studied, the greatest number of items with statistically significant different patterns of responses occurred between the Std. 8 (Year 10) Cape Town group and their Year 10 Australian counterparts. Twenty of the 26 items yielded statistically significant differences on the modified VOSTS instrument. For the other three hypotheses, although some items yielded statistically significant differences between the comparative groups, there was large scale agreement on many of the items. Thus there is evidence to suggest that the instrument is sensitive to detecting areas of agreement and disagreement between the various groups.

The five groups, on average, gave the highest importance to items 1F (77%), 2E (75%) and 3A (66%) on the three scales respectively, viz.

- **Science is** *exploring the unknown and discovering something new about our world and universe;*
- **The scientific method is** *testing and retesting, proving something true or false in a valid way;*
- **Scientific knowledge** changes *because new scientists disprove the theories or discoveries of old scientists.*

Item 2K yielded the highest average percentage of "I don't know" responses. This item should possibly be reconsidered or rephrased.

The main empirical results of this study have been presented and briefly analysed in this chapter, but with little explanatory comment. A more detailed interpretation and discussion of the emerging trends now follow in Chapter 5.

CHAPTER 5

DISCUSSION OF RESULTS

The original VOSTS instrument, developed by Aikenhead et al. (1987), was designed to elicit views on science-technology-society (STS) issues held by Canadian high school graduates. However, the instrument did not lend itself to test-retest comparisons and hypothesis testing using inferential statistical procedures (Rubba et al., 1996:387).

In analysing and interpreting the results on the modified VOSTS instrument, I will use the interpretive framework outlined by Ryan and Aikenhead (1992:561), the "traditional" and "contemporary" models of the nature of science (Palmquist and Finley, 1997:597), as well as other perspectives found in the literature. Finally, I will compare and contrast my findings in South Africa with those of Ogunniyi (1999), also in South Africa, where some of his particular items were relevant to the present study.

5.1 Defining Science (Items 1A to 1J)

On Scale One of the modified VOSTS instrument, students were asked to respond to ten statements which define science. These statements were taken from interviews or written responses by students (N>2000) during the development of the original VOSTS instrument. Thus, they reflect the perspective of the respondents, and not the viewpoint of the researcher (Aikenhead and Ryan, 1992:479).

When interpreting the student responses to statements on the epistemology of science, it is useful to look at three aspects of science, viz. science content, science process and the social context of science (Ryan and Aikenhead, 1992:562). The "traditional" and "contemporary" models of science are derived from the logical empiricist and post-positivist schools of thought respectively (Palmquist and Finley, 1997:597).

It is pertinent that, for each of the four local samples, the highest percentage of students responded that **science is** *exploring the unknown and discovering something new about our world and universe* (item 1F). This corroborates the finding of Parker and Rochford (1995) in which 58 out of 82 (71%) aspirant young scientists in Cape Town schools also believed that this item played a "major part" in defining science. This process-oriented view of science represents a realistic perspective which corresponds to the "contemporary" model of science as an organisation of our knowledge to help us learn about nature. Ogunniyi (1999: 230) also found in his study that 83% of teachers and 91% of pupils agreed that science shows the truth about nature; and 98% of teachers and 68% of pupils agreed that science helps us to describe, explain and predict events as accurately as possible.

By contrast, 81% of the Australian students and 78% of the college of education students in Cape Town responded that **science is** *finding cures for diseases and helping the environment* (item 1B). This represents a naïve view of a definition for science which does not distinguish between the social purposes of technology (to respond to human and social needs) and the inherent nature of science itself. Possibly this is a case of students being socialised to think that "technology is applied science".

Their views support the "contemporary" model which sees science as part of human progress. The standard 8 and standard 10 samples were in agreement on item 1B.

Another preconceived image of science as promoting technological advancement is revealed in item 1A, i.e. **science is** *inventing or designing things*. Significantly, 83 out of 108 (77%) electrical engineering students responded that this is a "major part" of science. It is not surprising that they subscribed to the view of "technology is applied science", given the nature of the discipline which they have chosen to study. This can also be seen as a "contemporary" view in which science is perceived as a competitive enterprise. Ogunniyi (1999: 230) found in his recent study that 72% of pupils and 88% of teachers agreed that thanks should be given to science for giving us refrigerators, television, radios, etc.

The standard 8 and standard 10 groups' responses diverged on some content and process aspects of science. Item 1I, i.e. **science is** *a body of fundamental ideas, such as principles, laws and theories*, revealed the most disparate positions on Scale One for these two groups. After three years of senior science it is suggested that the standard 10 students might have attached greater importance to the view that the content of science consists of laws and theories. This suggests that they might have tended to hold a more "traditional" view of science whose goal is to pursue the absolute truth, but whether the difference was due to increasing maturity, or due to the classes having different science teachers is not known. Items 1C and 1G represent process and content views of science respectively, or they may be viewed as representative of the "traditional" and "contemporary" models respectively. The standard 8 group considered these items 1C and 1G to play a "major part", 63% and 68%, respectively, in defining science. Only 44% and 48% of their Australian counterparts believed that these two items, 1C and 1G respectively, played a "major part". Thus, no consistent overall view of science appeared to exist between these two inter-continental samples of students with respect to these particular items.

Further comparative examination of the percentages of responses of the standard 10 and the tertiary level students disclosed a substantial measure of concurrence on the content and process aspects of science, e.g. 63% of standard 10 and 63% of electrical engineering students viewed item 1I as playing a "major part" in defining science.

Individual science educators at secondary and tertiary level also have their own particular views of the nature of science. For example, if they teach basic scientific principles by merely explaining them during lectures, the impression may be created that contemporary science is a body of knowledge which is certain (Palmquist and Finley, 1997:595). However, Alters' study (1997:48) concluded that the science education research community should acknowledge that exists no one agreed-upon nature of science.

Curriculum 2005 aims to develop learners who are "critical" thinkers; who are able to integrate knowledge; and who can learn relevant topics connected to real-life situations. *The results of this current investigation indicate that, when defining science, the samples of South African students tended to hold more "contemporary" views of science* on various items. Thus, the students adopted a more holistic approach to knowledge integration in some respects, which is in line with what Curriculum 2005 hopes to achieve.

5.2 Perceptions of the Scientific Method (Items 2A to 2K)

Scale Two of the modified VOSTS instrument comprises eleven statements which address the perceptions of scientific method. While there is no universally accepted view of scientific methods, it is feasible to analyse the student responses in terms of an inductive or deductive approach - both are traditional views. An inductive approach assumes that observations will lead to the derivation of certain laws and theories which explain them (Hodson, 1982:112). In the science curriculum this may be given as a prescriptive procedure to follow in the laboratory - the "traditional" approach. Deduction is the reverse process in which laws and theories are first hypothesised and predictions are then made from these. These may be contrasted with the "contemporary" model which proposes that there is no single scientific method, i.e. a step-by-step process.

Item 2E, i.e. **the scientific method is** *testing and retesting, proving something true or false in a valid way,* was chosen by all five comparative groups as the more important description of the scientific method. This finding is consistent with the results reported by Parker and Rochford (1995) for aspirant young scientists and mainstream students. This item describes the scientific method in the Popperian sense whereby a theory is experimentally validated - the hypothesis is either supported or rejected. The majority of such students therefore subscribe to the hypothetico-deductive method (Hodson, 1982:113), i.e. they tend to favour the "traditional" approach. It would be interesting to elicit students' views on what constitutes a "valid way" of testing.

Item 2F, i.e. **the scientific method is** *postulating a theory, then creating an experiment to prove it,* is also a typical formulation of the deductive approach. Student responses were largely in agreement with this statement as a description of the scientific method. From a theoretical aspect this item is typical description of the "contemporary" model, but it conforms to the "traditional" model if the actual experiment follows a step-by-step process.

The wording of item 2I reads that **the scientific method** *is a logical and widely accepted approach to solving problems.* A hypothesis is first produced, then it is logically investigated - this is the deductive approach. The views of four of the sample groups, except the Australian sample, concurred on this item which is a "traditional" view. Parker and Rochford (1995) had similar findings on this item.

Fewer than half of the students (47% across the samples) perceived the scientific method as a textbook-prescribed laboratory procedure (item 2A) - this being the inductive approach of making observations, then arriving at a theory. However, this does not suggest that they held "contemporary" views of the scientific method. Again, this corroborates the findings of Parker and Rochford (1995).

Item 2G is also a typical descriptor of the inductive ("traditional") approach. Comparisons of student responses were varied on this item - the standard 8, standard 10 and college of education students concurred, whereas the standard 8 vs. year 10 (Australian) and standard 10 vs. electrical engineering students held widely dissimilar views. The high school and college of education science students had been exposed extensively to this method of doing laboratory work. However, the majority of engineering students in this particular study came from a background of non-exposure to laboratory work. This possibly explains why they were divided on this item, i.e. 41% chose the "major part" and 41% selected the "minor part" response.

Further evidence of a wide acceptance of the inductive ("traditional") method is provided by the comparative percentage responses on item 2B, i.e. **the scientific method is** *recording your results carefully* - 71% of standard 8, 77% of standard 10 and 71% of college of education students considered this to play a "major part". Seventy five percent of standard 8 and 77% of standard 10 students also held the view that being accurate and not making errors (item 2H) is a "major part" of the scientific method. It is interesting to note (but also possible cause for concern) that only 38% of the electrical engineering sample considered this to play a "major part". Besides the reasons outlined above, there may be other factors which played a part in their choice of response. Parker and Rochford (1995) also found 76% and 68% of the EXPO students respectively viewed items 2B and 2H to play a "major part".

The last item on Scale Two received a high percentage of "I don't know" responses from all five samples. A contemporary view is that "there really is no such thing as the scientific method" (Ryan and Aikenhead, 1992: 572). It is not surprising that students responded "I don't know" to item 2K which subscribes to the "contemporary" model. Palmquist and Finley (1997:610) showed that teachers had a "traditional" view of the scientific method which they portrayed in the classroom. Thus, students might not have been directly exposed to the "contemporary" view in the classroom. In terms of Curriculum 2005, it is interesting to note that while many of the students defined science mostly in a "contemporary" sense, they still perceived the scientific method in the "traditional" way, i.e. many students still needed to develop critical thinking in terms of "contemporary" views.

5.3 Perceptions of scientific knowledge (Items 3A to 3E)

Scale Three of the modified VOSTS instrument consists of five statements which examine how scientific knowledge changes. The statements retained the same wording as in the original VOSTS instrument. They address the tentative nature of scientific knowledge without mentioning the term "tentative" (Ryan and Aikenhead, 1992: 575).

Analysis of the comparative percentage responses shows that the majority of students considered item 3A to play a "major part" in the changing nature of scientific knowledge. This characterises a falsificationist position whereby the old scientific facts are *disproved* by new investigations. Hodson (1982:113) contended that falsification, rather than verification, is the central feature of Karl Popper's philosophy. The "traditional" model propounds the view that scientific knowledge is proven or disproven owing to the direct influence of observations.

In *The Structure of Scientific Revolutions* Thomas Kuhn (1970) proposed that science proceeds by successive phases of "revolution" and consolidation (Hodson,1982:114). Item 3B, i.e. **scientific knowledge** *changes because the old knowledge is reinterpreted in the light of new discoveries*, depicts this paradigm shift to which Kuhn refers. On scale three a large percentage of students perceived this contemporary constructivist view to play a "major part". However, this is not sufficient evidence to conclude that the students held a Kuhnian perspective, except to suggest that they indicated their belief that scientific knowledge or "facts" can change, i.e. scientific knowledge is tentative.

On item 3C, i.e. **scientific knowledge** *changes because the earth's physical environment changes and this affects the outcome of investigations,* most students responded that it played a "minor part". Sixty four percent of the sample of college of education students held this view. The response patterns were uniform, except for the standard 10 vs. college of education students. This portrays a realistic view on the tentative nature of scientific knowledge, unencumbered by the changes in nature. Scientific investigations are normally carried out under controlled conditions.

Item 3D expresses the view that old scientific facts do not change - only their interpretation and application change. This absolute ("traditional") view of science as yielding unchangeable facts was identified as "excessive rationalism" by Nadeau and Desautels (1984; cited by Ryan and Aikenhead, 1992:561). The students were equally divided as to whether this item played a "major part" or "minor part" on Scale Three.

The last item (3E) on Scale Three also depicts an absolute view that the old facts do not change, but new knowledge is added onto old knowledge. This out-dated epistemic perspective describes the progress of science as simply an accumulation of knowledge (Ryan and Aikenhead, 1992:576). Sixty percent and 49% of the college of education and electrical engineering students, respectively, believed that this item played a "major part". The other students were divided on this cumulative perspective of scientific knowledge.

The students appeared to hold mixed views (either "traditional" or "contemporary") on the last scale of the modified VOSTS instrument. This supports the view that there is no single view of the nature of science, and is also consistent with the findings of Ayayee and McCarthy (1995: 102). In terms of the new curriculum, the students' level of scientific literacy may be enhanced if they are exposed to more contemporary views in the classroom.

5.4 Adaptation of the study for Curriculum 2005

The new Curriculum 2005 (1997) has eight clearly defined learning areas - two of these being Technology and Natural Sciences. While the original VOSTS has a pool of 114 items to choose from, the modified VOSTS used in this study is limited in its scope. In the future a number of changes will have to be made to make it more student-friendly in terms of Curriculum 2005, and in terms of the recent release of definitive publications by the AAAS (1999a and 1999b) on the current understanding of the nature and methodology of science and technology:-

- An analysis of the items and of some of the incongruous responses indicated that some items may possibly have to be rephrased. These are items 1B, 1D, 2C, 2K and 3C;
- A separate scale for technology will have to be introduced; and
- provision must be made for students to motivate their responses.

5.5 Chapter Summary

The main aspects in the epistemology of science on which this study focused were: the definitions of science, the nature of the scientific method and the tentativeness of scientific knowledge.

In defining science, the majority of students expressed the realistic view that **science is** *exploring the unknown and discovering something new about our world and universe.* However, some did not distinguish between the social purposes of technology and the empirical role of science. The students also did not express consistent views on the process and content aspects of science.

Most of the students chose to define the scientific method in a deductive (formal logic) sense. However, a large proportion of students, especially high school students, endorsed the inductive approach. Both of these are "traditional" views. The view that there is no such thing as a scientific method, although a contemporary perspective, elicited a large percentage of "I don't know" responses. This item needs to be rephrased.

On the last scale, the majority of students agreed on the tentative nature of scientific knowledge. They attached greater importance to a falsificationist perspective as opposed to a constructivist view. Some, however, also held the view that scientific knowledge is absolute.

In the following chapter I offer some recommendations based on my findings in this empirical study, and present my conclusions.

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary

This empirical study measured and compared students' perceptions of the nature of science using a modified version of the VOSTS instrument. Four convenient sample groups were drawn from two local high schools, a technikon and a college of education. A fifth sample was taken from a study in Australia where 434 Year 10 students' views of science were recorded. These findings were compared with the corresponding views of their South African counterparts.

Two non-parametric statistical tests, the Mann-Whitney U-test and χ^2 - test, were used to determine any statistically significant differences between the sample groups. All four null hypotheses were rejected. The highest percentage of students perceived science as *exploring the unknown and discovering something new about our universe*; the scientific method was perceived as *testing and retesting, proving something true or false in a valid way*; and scientific knowledge changes *because new scientists disprove the theories or discoveries of old scientists*. All the results were analysed and interpreted in terms of a "traditional" and "contemporary" model of science.

The samples of South African students tended to hold more "contemporary" views of science when defining science, they perceived the scientific method in the "traditional" way, and the students appeared to hold mixed views (either "traditional" or "contemporary") on the .ast scale of the modified VOSTS instrument.

6.2 Conclusions

Students' perceptions of science are informed by their knowledge of a number of different aspects of science. Student knowledge of the theoretical concepts in science, and the methods used by scientists to investigate and perform experiments, are reinforced by the science curricula, the media and other informal experiences. However, knowledge about the nature of science, that is, how scientific knowledge is developed and used, is not explicitly taught, unless students follow a course in the history and philosophy of science.

The results of this study suggest that the modified VOSTS instrument available at the time, was a reliable and valid instrument which was sensitive to detecting areas of agreement and disagreement between the various groups surveyed. They also add credence some of the objectives of Curriculum 2005 with regard to scientific literacy in the learning area of Natural Sciences.

Students perceived science as a process of discovering the world, but they partially failed to see how social activities might influence the acquisition of knowledge. Their formal learning experiences might also have led to the development of naïve views which do not distinguish between the roles of science and technology. Most of the students perceived the scientific method in a "traditional" way, that is, as a step-by-step process approach. The majority of students also agreed on the tentative nature of scientific knowledge, and attached greater importance to the falsifiablity of an investigation. This view can be contrasted with the constructivist perspective which does not view knowledge construction as independent of our thoughts and theoretical commitments.

If students' perceptions of the nature of science can impact upon their learning, then the challenges facing science educators may be appreciable, and it may be difficult to influence views which have been constructed during years of formal education. However, sustained efforts must continue to be made to promote scientific literacy at both the macro and micro levels.

6.3 Recommendations

The following recommendations are made regarding the study as a whole:

1. The content of the STS topics for use in future research can be expanded, including specific scales for technology. Other topics which might possibly be included are: the impact of science and technology on the environment; the social roles of scientists, engineers and technologists; etc. Careful item selection has a direct bearing on the content validity and the constructs to be measured.

2. In future studies the instrument must be updated and redesigned to incorporate the different cultural aspects of our population and Curriculum 2005 criteria. The instrument might also be modified and translated into Xhosa or Zulu, or any other indigenous language which is dominant in a particular region.

3. Comparisons can then be made between the various cultural or language groups' views of science and technology.

4. Curriculum 2005 must include specific topics on the nature of science and technology so that the desired outcome of having scientifically literate individuals might be realised.

5. Students' responses must be followed by a semi-structured interview so that they may motivate their responses in a South African context.

6. It is suggested that science teachers might undertake a course in the History and Philosophy of Science during their teacher training. This might enhance their ability to impart knowledge in the classroom when the nature of science and technology is dealt with, and this suggestion could be investigated in future.

7. Long-term studies might also be carried out to determine whether science students' views change as they progress to a higher educational level. The assumption would be that the sample groups remain intact over a long period; this methodological approach may just not be practical.

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APPENDIX A

Publications: Two conference papers and a journal article

Southern African Association for Research in Mathematics and Science Education

PROCEEDINGS

7TH ANNUAL SAARMSE CONFERENCE

Editor

Jaap Kuiper

JANUARY 13-16, 1999

HARARE

ZIMBABWE

STUDENTS' PERCEPTIONS OF THE NATURE OF SCIENCE AND TECHNOLOGY, SCIENTIFIC METHOD AND KNOWLEDGE

AN INTERNATIONAL COMPARISON

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In 1995 a class of N=340 year 12 (final year) high school science students in Cape Town responded to 26 items on the modified VOSTS scales, which measure perceptions of the nature of science and technology, scientific method and knowledge of science and technology - after Evans and Schibeci (1991). Item by item, their response patterns were then compared with the corresponding response patterns of three other samples in Cape Town in 1995. These were : N=320 year 10 high school science students; N=55 first year college of education science students and N=108 technical students at one of the technikons in Cape Town. The response patterns obtained with the four samples in 1995 were also compared with those available from a sample of 434 year 10 high school science students obtained in Western Australia surveyed in 1991. The five samples, on average, attributed the highest importance to the VOSTS item "Science is exploring the unknown and discovering something new about our world and universe". Comparing pairs of the five samples of students, however, the year 10 Cape Town science class and the year 10 Perth science class produced response patterns which were significantly different on all but six of the 26 VOSTS items. In Cape Town the response patterns of the sample pairs of technikon and science students showed close agreement. However, several items revealed highly significant response differences with the technikon students. These concerned science as inventing or designing things; finding and solving puzzles; and the nature of the processes involved in scientific method. The findings are presented and discussed in the special context of both the "traditional" model and the "contemporary" model of the nature of science.

Introduction

In their investigation into preservice teachers' views on the nature of science during a postbaccalaureate science teaching programme, Palmquist & Finley (1997:595) explained why science teachers need to recognise the nature of scientific endeavour and how it relates to science teaching. Their research concluded that most of the preservice teachers had definite views of various aspects of the nature of science which were either "traditional" or "contemporary".

Their work was a sequel to the studies of several earlier investigators, such as Aikenhead, Flemming & Ryan (1987); Aikenhead (1988); and Aikenhead & Ryan (1989); and it was in that particular context that the current study was conducted, and is now presented.

Background of the Study

In 1987 Aikenhead et al. developed an instrument for determining Views of Science-Technology-Society (VOSTS). The content of the scales was defined by the domain of science-technology-society (STS) topics appropriate for high school students. Initially, a pool of 114 items was developed by producing choices which were empirically derived from students' writings and from a series of interviews. These were administered to more than 2000 grade 11 and 12 students in Canada, as a result of which there originated a distilled group of just 26 items clustered into three coherent scales.

In 1991 Evans and Schibeci used a modified VOSTS instrument to assess 343 Australian students' views on selected aspects of the STS theme; and in South Africa Parker and Rochford (1995), and Edwards et al. (1997), conducted further corroborative studies with more than 1400 South African students.

The modified VOSTS instrument used 26 items to measure students' views on three scales, commencing with the lead headers: "Science is...", "The scientific method is..." and "Scientific knowledge..." respectively.

Purpose

In the light of the "traditional" and "contemporary" models of the nature of science, the purpose of this study was to compare and contrast the perceptions of different groups of science and technikon students on selected aspects of the science-technology society theme using the three VOSTS scales. It set out to evaluate the South African and Australian responses of five convenient sample groups, in the age range 15 to 19 years, in respect to the importance of 26 items on the modified VOSTS instrument of Evans and Schibeci (1991).

Its three subscales purport to measure student perceptions of: the nature of science (10 items); the scientific method (11 items); and how scientific knowledge changes (5 items).

Importance of the Study

At the same time as the work of Ogunniyi (1998), this study in Cape Town was carried out as one of many recent inter-related local investigations into people's perceptions of the world of science and technology; the effects of science and technology on traditional beliefs and culture; young people's attitudes towards science and technology in Africa; the popularization of science and technology; the state of science and technological literacy in Southern Africa; and the role of the communications media in public understanding of science and technology.

These studies were a sequel to the release, by the Foundation for Research Development (1996), of science-and-technology indicators showing underperformance in the South African context.

Methodology

The data was collected during normally scheduled lecture times or periods of instruction in physical science, biology, mathematics and engineering at the high schools, college and technikon respectively. The modified VOSTS instrument required approximately 15 minutes to administer and complete.
In order to detect the existence of significant differences between the response frequencies of the various groups, the patterns of responses (i.e. the headcounts of preferences) were analysed using chi-squared tests. When certain responses recorded fewer than five counts from a specific student sample for a section of a given item, the Mann-Whitney U-test was employed to test for statistical differences in those instances.

The Instrument

The modified VOSTS consisted of three scales comprising a total of 26 item statements, every one of which had to be rated as a perceived "major part", "minor part", "no part" or "I don't know" by each student respondent.

Hypothesis

The hypothesis sought to test whether any statistically significant differences existed between the frequencies of the choices of the five sample groups with respect to the relative importance of the 26 item statements constituting the modified VOSTS.

Results

Overall, the five groups, on average, attributed the greatest importance to the following items on the three scales:-

* "Science is exploring the unknown and discovering something new about our world and universe" (77%);
* "The scientific method is testing and retesting, proving something is true or false in a valid way" (75%); and
* "Scientific knowledge changes because new scientists disprove the theories or discoveries of old scientists" (66%).

All null hypotheses tested in this investigation were rejected by the data obtained for all five samples, on at least some of the 26 items comprising the VOSTS. For the Cape Town samples, however, there was widespread agreement (i.e. non-significant differences occurred) between various pairs of the samples, for many of the items. Thus there was ample evidence to suggest that the instrument was sensitive to detecting areas of agreement and disagreement between the various groups surveyed.

Item 1A reads, "Science is inventing or designing things (e.g. artificial hearts, computers, space vehicles, etc.)". It was found that 75% of the technikon students, but only 45% of the final year high school students, described this item as being a major part of science. There appears to be an appreciable difference between the thinking of science and technikon students on this item (z=5.86).

Item 1E reads, "Science is finding puzzles and solving them", but 31% of the technikon students said they thought this played no part in science. In this respect, the responses of the technikon students were significantly different from those of the science students (z=4.10).

However, the technikon students strongly favoured item 2G, "The scientific method is questioning, hypothesising, collecting data and concluding" (z=4.88), as well as item 2H, "The scientific method is being accurate and not making errors" (z=7.54).

Discussion

Palmquist & Finley (1997) provide a 30 point comparison between the "traditional" model and the "contemporary" model of the nature of science, under six common headings. They are Theory (T), Role of a Scientist (R), Scientific Knowledge (K), Scientific Method (M), Laws (L) and General (G). This is attached in Annexure A.

From the evidence provided by a total of 823 high school, college and technikon students in their responses to the items comprising the three scales of the modified VOSTS, it appears that different types of scientifically-orientated and technically-orientated students might perceive certain aspects of the theory of the nature of science, the role of a scientist, scientific knowledge, scientific method and the laws of science appreciably differently in some respects.

Conclusion

Science and technikon students' descriptions of science, the scientific method and scientific knowledge were found to be similar in some ways, but different in others, especially if the students were the products of education systems on different continents. These preliminary findings might be useful to future science and technology curriculum planners who choose to work in an outcomes based system of education with particular reference to scientific skills development.

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Appendix

TRADITIONAL MODEL OF THE NATURE OF SCIENCE

Theory (T)
1. Theories are based directly on observation.
2. New theories are improvements over old theories because observations improve and increase over time.
3. An entire theory is falsified if subject to a single contradictory fact.
4. A theory is a hypothesis that has been proven to be correct.
5. Old theories are of no use to scientists.

Role of a Scientist (S)
1. A scientist evaluates scientific claims exclusively through empirical evidence.
2. All actions of a scientist are assumed to be open-minded andobjective.
3. A scientist is someone who uses the traditional scientific method.
4. A scientist strives to discover the absolute truth.
5.1 Scientists must avoid being influenced by anything outside of "pure" science.
5.2 Scientists must report data exactly as their senses perceive it.

Scientific Knowledge (K)
1. Scientific knowledge corresponds to reality.
2. Scientific knowledge increases by accretion from observations.
3. Scientific knowledge progresses by an accumulation of observations.
4. Scientific knowledge is proven or disproven owing to the direct influence of observations.
5.1 Scientific knowledge is unchanging.
5.2 Scientific data must not be interpreted by the scientist.

Scientific Method (M)
1. Science relies on precise control of experiments (and match with prediction) for proof.
2. The use of the traditional scientific method is necessary to discover and validate theories.
3. There is a single method for doing science.
4. The scientific method is a step-by-step process.
5.1 The method must be planned out in advance of the inquiry.
5.2 When a scientist uses the traditional scientific method correctly, the results are true without doubt.

Laws (L)
1. Scientific laws are found directly in nature.
2. Scientists interpret the laws found in nature.
3. Scientific laws can be proven to be absolutely true.
4. Laws are proven theories.

General (G)
1. Science is only the set of findings called scientific knowledge.
2. Explaining an event consists of carefully reducing that event to known knowledge.
3. Progress consists of discovering theories that represent a closer approximation to the absolute truth.
4.1 Science is "doing experiments".
4.2 The goal of science is to find the absolute truth.

CONTEMPORARY MODEL OF THE NATURE OF SCIENCE

Theory (T)
1. Observations are theory-laden.
2. Theories are the inventions of scientists.
3. The occurrence of a contradictory fact does not necessarily compel the abandonment of a theory.
4. Theories are tools used to describe, explain and predict scientific phenomena.
5. Theories fit within certain paradigms.
6.1 A scientist's initial notions of where to start an inquiry are theory laden.
6.2 Theories are validated by their connection to other, generally accepted theories.
6.3 Observations are influenced by social factors.

What a Scientist Does (S)
1. The primary act of a scientist is often a leap of imagination or creativity.
2. A scientist interprets results based on prior knowledge, observation, logic and social factors.
3. Scientists create theories based on prior knowledge, observation and logic.
4. A scientist works within the scientific community to evaluate and contemplate the work of other scientists.
5.1 Scientists make decisions before inquiry based on prior knowledge, observation, logic, and social factors.
5.2 A scientist is someone who is curious.
5.3 Scientists communicate with other members of the community.
5.4 A scientist is influenced by past research.
5.5 The first inclination of a scientist is to try to integrate new knowledge into old knowledge.

Scientific Knowledge (K)
1. The progression of scientific knowledge is not continuous.
2. Scientific knowledge is tentative.
3. Scientific knowledge is created and validated by common acceptance within the scientific community.
4. Scientists create knowledge based on prior knowledge, observation, and logic.
5.1 The tentativeness of knowledge is related to how much people work on it.
5.2 The truth is defined as an accurate description of nature.

Scientific Method (M)
1. Scientists are not compelled to use the traditional scientific method.
2. There is no single scientific method.
3. Methods used by scientists depend on circumstances.
4.1 Knowledge can be gained by means other than the scientific method.
4.2 Scientists can adjust their method of inquiry in the middle of an investigation and still obtain valid results.
4.3 The traditional scientific method is simply one possible guide for inquiry.

Laws (L)
1. Laws are created by scientists.
2. Laws are validated within the scientific community.
3. Laws are a scientist's best attempt to explain some part of nature.

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STUDENTS' PERCEPTIONS OF THE NATURE OF SCIENCE AND TECHNOLOGY, SCIENTIFIC METHOD AND KNOWLEDGE: A COMPARISON OF THE RESPONSES OF ENGINEERING AND SCIENCE STUDENTS IN CAPE TOWN AND PERTH

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ABSTRACT

In 1995 a class of 108 electrical engineering students in Cape Town responded to 26 items on the modified VOSTS scales, which measure perceptions of the nature of science and technology, scientific method and knowledge of science and technology - after Evans and Schibeci (1991). Item by item, their response patterns were then compared with the corresponding response patterns of three other samples in Cape Town in 1995. These were : 340 year 12 (final year) high school science students; 320 year 10 high school science students; and 55 first year college of education science students.

The response patterns obtained with the four samples in 1995 were also compared with those available from a sample of 434 year 10 high school science students obtained in Perth, Australia, in 1991.

The five samples, on average, attributed the highest importance to the VOSTS item "Science is exploring the unknown and discovering something new about our world and universe" (77%). Comparing pairs of the five samples of students, the year 10 Cape Town science class and the year 10 Perth science class produced response patterns which were significantly different on 20 of the 26 items; but the response patterns of the sample pairs of engineering and science students in Cape Town showed closer agreement. With the engineering students, however, five items revealed highly significant response differences.

1. INTRODUCTION

In his paper addressed to the National Seminar on Engineering Education in South Africa in 1997, Tom Ryan argued that the scientific method could be explicitly integrated into engineering students' learning experiences. He concluded that the scientific method offered a good base for a learning model that could help prepare engineering students for practice in a changing South Africa [1].

The National Seminar was convened as a sequel to the release of the White Paper on Education and Training in a Democratic South Africa: First Steps to Develop a New System. In its Statement of Values and Principles o f Education and Training Policy, the White Paper states that an appropriate mathematics, science and technology initiative is essential to make up the chronic national deficit for economic advancement [2].

2. BACKGROUND OF THE STUDY

In 1987 Aikenhead et al. developed an instrument for determining Views of Science-Technology-Society (VOSTS). The content of the scales was defined by the domain of science-technology-society (STS) topics appropriate for high school students. Initially, a pool of 114 items was developed by producing choices which were empirically derived from students' writings and from a series of interviews. These were administered to more than 2000 grade 11 and 12 students in Canada [3, 4].

In 1991 Evans and Schibeci used a modified VOSTS instrument to assess 343 Australian students' views on selected aspects of the STS theme [5]; and in South Africa Parker and Rochford in 1995, and Edwards et al. in 1997, conducted further corroborative studies with more than 1400 South African students [6;7]. The modified VOSTS instrument used 26 items to measure students' views on three scales, commencing with the lead headers: "Science is...", "The scientific method is..." and "Scientific knowledge..." respectively.

3. PURPOSE

The purpose of this study was to compare and contrast the perceptions of different groups of science and engineering students on selected aspects of the science-technology society theme. It set out to evaluate the South African and Australian responses of five convenient sample groups, in the age range 15 to 19 years, in respect to the importance of 26 items on the modified VOSTS instrument of Evans and Schibeci (1991). Its three subscales purport to measure student perceptions of: the nature of science (10 items); the scientific method (11 items); and how scientific knowledge changes (5 items).

4. IMPORTANCE OF THE STUDY

This study in Cape Town was carried out as one of many recent inter-related local investigations into people's perceptions of technology; the effects of science and technology on traditional beliefs and culture; young people's attitudes towards science and technology in Africa; the popularisation of science and technology; the state of science and technological literacy in Southern Africa; and the role of the news media in public understanding of science and technology [8]. These studies were a sequel to the release, by the Foundation for Research Development, of science-and-technology indicators showing underperformance in the South African context in 1996 [9].

5. METHODOLOGY

The data was collected during normally scheduled lecture times or periods of instruction in physical science, biology, mathematics and electrical engineering at the high schools, a college and a technician respectively. The modified VOSTS instrument required approximately 15 minutes to administer and complete. In order to detect the existence of significant differences between the response frequencies of the various groups, the patterns of responses (i.e. the headcount of preferences) were analysed using chi-squared tests. When certain responses recorded fewer than five responses from a specific student sample for a section of a given item, the Mann-Whitney U-test was employed to test for statistical differences in that instance.

6. THE INSTRUMENT

The modified VOSTS consisted of three scales, a full copy of which is attached in Appendix 1. The scales comprised a total of 26 item statements, every one of which had to be rated as a perceived "major part", "minor part", "no part" or "I don't know" by each respondent.

7. HYPOTHESIS

The hypothesis sought to test whether any statistically significant differences existed between the frequencies of the perceptions of the five sample groups with respect to the importance of the 26 item statements given on the modified VOSTS.

8. RESULTS

Overall, the five groups, on average, attributed the greatest importance to the following items on the three scales:

Item 1F (77%): "Science is exploring the unknown and discovering something new about our world and universe"; Item 2E (75%) : "The scientific method is testing and resetting, proving something is true or false in a valid way"; and, Item 3A (66%) : "Scientific knowledge changes because new scientists disprove the theories or discoveries of old scientists".

Item 2K yielded the highest average percentage of "I don't know" responses, and consequently it is recommended that the original wording of this item be reconsidered or rephrased by its authors.

All null hypotheses tested in this investigation were rejected by the data obtained for all five samples, on at least some of the 26 items comprising the VOSTS. For the Cape Town samples, however, there was widespread agreement (i.e. non-significant differences occurred) between various pairs of the samples, for many of the items. Thus there was ample evidence to suggest that the instrument was sensitive to detecting areas of agreement and disagreement between the various groups surveyed.

For example, the null hypothesis, "that no statistically significant differences exist between the responses of 340 final year high school students in Cape Town and the responses of 108 electrical engineering students in Cape Town to the 26 statements on the modified VOSTS measure" was rejected. Five of the 26 items yielded highly significant differences ($p<0.01$) between the two groups (high school, H.S.; and electrical engineering, E.E.), as indicated below:-

Item number	"Major part" H.S.	E.E.	"Minor part" H.S.	E.E.	"No part" H.S.	E.E.	Z-test statistic
1A	45%	75%	42%	20%	10%	1%	5.86
1E	40%	29%	46%	32%	12%	31%	4.10
2G	70%	41%	18%	41%	3%	14%	4.88
2H	77%	38%	16%	41%	3%	17%	7.54
3C	38%	25%	42%	40%	14%	31%	3.21

9. DISCUSSION

Item 1A reads, "Science is inventing or designing things (e.g. artificial hearts, computers, space vehicles, etc.)" It was found that 75% of the engineering students, but only 45% of the final year high school students, described this item as being a major part of science. In this way there appears to be an appreciable difference between the thinking of science and engineering students.

Item 1E reads, "Science is finding puzzles and solving them", but 31% of the engineering students said they thought this played no part in science. In this respect, the engineering students were distinctly different from the science students. However, the science students strongly favoured item 2G, "The scientific method is questioning, hypothesising, collecting data and concluding", as well as item 2H, "The scientific method is being accurate and not making errors".

10. CONCLUSION

Science and engineering students' descriptions of science, the scientific method and scientific knowledge were found to be similar in some ways, but different in others, especially if they were the products of education systems on different continents. These preliminary findings might be useful to curriculum planners working in an outcomes based system of education.

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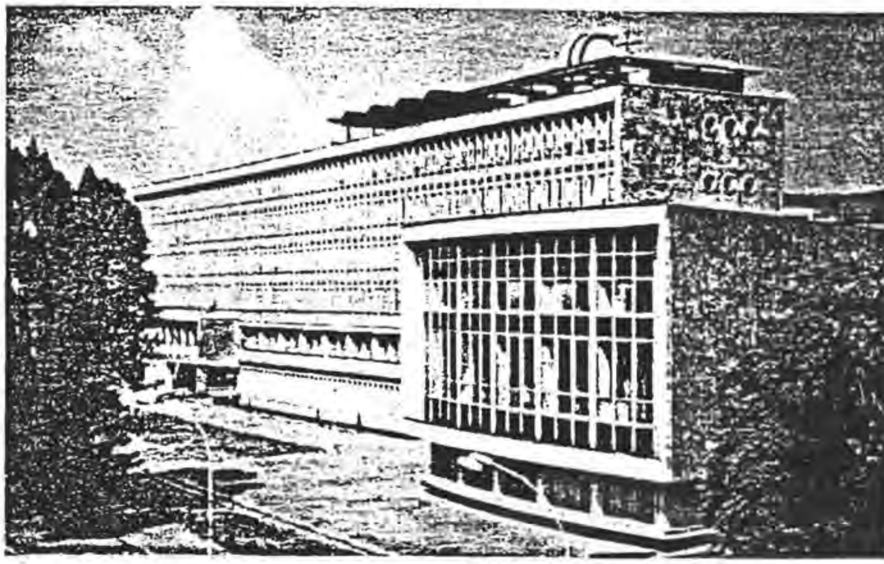

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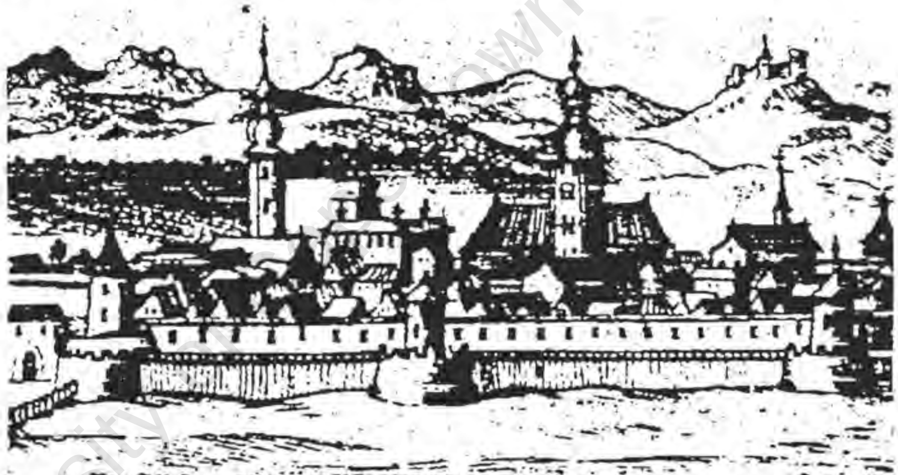

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GENDER DIFFERENCES AMONG STUDENTS' PERCEPTIONS OF SCIENCE AND TECHNOLOGY

ABSTRACT

In 1994 modified Aikenhead scales were employed to evaluate the views on Science, Technology and Society (VOSTS) held by 499 female and 498 male 15- to 17-year-old students enrolled in two single-sex high schools in Durban, South Africa. A statistical analysis of the group responses of the males and females to 26 items on the three modified VOSTS scales disclosed significant perceptual differences on 15 items. In an earlier pilot study using VOSTS items, the findings of Zoller et al. (1990) suggested that gender might play a significant role in accounting for differences in STS viewpoints. This more recent amplified South African study supports their hypothesis. The investigation is therefore being extended to engineering and technikon students in 1996- 1997 in South Africa.

INTRODUCTION

The establishment of a new democratic order in South Africa has brought about the country's readmission into the community of Commonwealth nations. South Africa now has the added advantage of increased economic and technical co-operation with other nations. The South African minister of Trade and Industries has also been negotiating bilateral agreements with Indian Ocean Rim countries (Race Relations Survey, 1994/5). It is against these positive developments that South African science and engineering educators are faced with the problem of imparting knowledge and skills to young people in an increasingly competitive technological world.

Citizens in a modern society also need to be scientifically literate in order to make informed decisions on personal technical issues as they arise in everyday life. One task of teachers and lecturers is to shape this scientific awareness in such a way that positive attitudes towards science and technology in the home, in the community and in the nation are encouraged and developed. One way of doing this is to begin by evaluating students' current views on selected aspects of science, technology and society (VOSTS). This may lead to the development of a more appealing curriculum which includes both science and technology.

In the past, however, the domain of science and technology has tended to be male-dominated, so possible reasons for this gender imbalance may need to be determined at the same time if a new curriculum is to be made more attractive to girls as well.

Weinburgh (1995) has reviewed the literature between 1970 and 1991 to analyse gender differences in student attitudes towards science. Her findings suggest that males may have shown a more positive attitude toward science than females. However, she points out that more research is needed in this field, particularly with reference to gender differences. Swarbrick (1996) has also presented a review of women in engineering initiatives from 1994 - 1996 in Australia; and a knowledge of differences in gender perceptions may have implications for the pedagogical and psychological training of technical teachers discussed by Prokopovic et al. (1996).

In their Declaration of Intent, the Gender Working Group of the UN Commission on Science and Technology sets out six goals for all governments. Two of these goals are that they should agree to work towards ensuring equal opportunities for men and women to acquire advanced training in science and technology, and to achieve gender equity within S&T institutions (cited by Appleton, 1995).

This study - conducted in 1994 in two single-sex high schools in Durban, South Africa - evaluates the views of a sample of 15-17- year-old male and female students in years 10, 11 and 12 towards science, technology and society. This investigation expands on the earlier findings of Aikenhead (1987, 1988) in Canada, Evans and Schibeci (1991) in Australia and of Parker et al. (1995) in Cape Town, South Africa, and is currently being extended to first year engineering and technikon students in Cape Town in 1996 and 1997.

BACKGROUND

Schibeci and Kissane (1994) cite Garfield's definition of a scientifically literate person as one who has

an understanding of the nature and limits of science, a mastery of basic conceptual knowledge in the major disciplines, and a sense of the social, cultural and ethical implications of science and technology.

Miller (1983) suggested that the concept of scientific literacy is three-dimensional, i.e. that it includes norms and methods of science, cognitive science knowledge, and the impact of science and technology on society. The 26-item modified VOSTS instrument measures student views on three scales, viz. *"Science is ..."*, *"The scientific method is ..."*, and *"Scientific knowledge ..."*

Appleton (1995) poses the question: "Does 'Science and Technology' impact differently on men and women?" She contends that studies have shown that technical improvements have been inappropriately formulated and designed and that women are, by and large, excluded from decision-making and practice in the science and technology arenas. Little research has also been done that examines gender issues from a S&T perspective. Fraser-Abder et al. (1995) suggest six critical areas which need to be explored in the S&T debate: the question of access to S&T, the S&T curriculum, teacher education, the teaching and learning environment, career opportunities and training of women.

Since there is a great gender disparity in the proportion of girls entering science and technology, Niblaeus (1991) has suggested that vocational guidance teachers should encourage girls to pursue careers in these fields. Israelsson (1991) and Mares et al. (1996) have argued that teaching practices are crucial in forming the attitudes of girls towards science and technology, and Levin et al. (1991) concluded that boys perform better than girls, particularly in the physical sciences.

The VOSTS instrument was developed by Aikenhead, Fleming and Ryan in 1987. In 1991, using a modified VOSTS instrument, Evans and Schibeci assessed 434 Year 10 students in three Perth metropolitan high schools. In 1993 Parker et al. used the modified VOSTS instrument to measure the views held by 82 young aspirant scientists and technologists, as well as by 391 mainstream senior high school students in Cape Town. He found six significant response differences to VOSTS items between the two samples. However, he found no significant differences between the Perth and Cape Town samples of mainstream science students, indicating that these high school students in English-speaking Western cities had similar views on science, technology and society.

PURPOSE

The purpose of the 1994 study in Durban, South Africa, was to determine whether or not gender differences existed in the senior high school students' views on STS, using the 26-item modified VOSTS instrument and, if so, to try to account for these.

METHOD

During March 1994 the 26-item modified VOSTS instrument was administered to 997 students enrolled at two well established single-sex high schools in Durban. The sample consisted of 498 males and 499 females, age range 15 to 17 years, mostly of middle class background.

INSTRUMENT

The modified VOSTS instrument itself consists of three scales. The first scale measures the strength of students' perceptions of the *nature* of science and technology (ten items); the second scale measures students' perceptions of the *scientific method* (eleven items); and the third scale measures students' perceptions of how scientific knowledge *changes* (five items). Students are asked to rate statements associated with each scale by choosing one of the following: major part; minor part; no part ; or I don't know.

DATA ANALYSIS

The item responses were used, firstly to derive response frequencies on all three scales; and secondly to determine significant gender differences among the response frequencies themselves.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 record the responses of the male and female students to each of the 26 items on the modified VOSTS scales.

The sizes of the male (N=498) and female (N=499) samples are virtually equal.

Fifteen of these items yield significant c^2 differences at the p=0.01 level for the two samples.

The results of the c^2 analysis of the data show that on **Scale One** ("*Science is ...*") the greatest sex differences occur on items 1D, 1E and 1J. The Durban male and female students seem to have significantly discrepant views about the relative role of scientific apparatus, finding puzzles and solving them, and a study of new ideas about the world around us as a description of science. The female students view science-technology more as a practical subject than the male students because science is purportedly geared towards solving problems posed by the physical environment.such as in engineering.

There is agreement on the relative importance of items 1A, 1H and 1I, with respect to science and technology being inventing or designing things, a body of knowledge and information based on facts and a body of fundamental ideas.

It is noteworthy that both male and female students give the highest weighting to item 1F as a description of science and technology. From the student perspective, science in society is to explore the unknown and to discover something new about our universe. In contrast, Parker's findings in 1993 with Cape Town students show that item 1F is given the second highest weighting.

It is clear that, although no uniform description of science and technology exists among the male and female students, large scale common trends do emerge. Both sub-groups ascribe a social purpose of technology to science (Items 1A and 1B) by having the conception of science as improving the world. They also tend to hold the nad've view that science can explain how things works (Item 1C).

An analysis of the magnitude of gender differences on **Scale Two** shows that the most significantly different responses occur with items 2G, 2E, 2B and 2D respectively. The male and female students as sub-groups are appreciably disproportionate on the role in science of questioning, hypothesising, collecting data, testing and retesting, recording results, and efficiently getting facts or theories, as a description of the scientific method. Significantly more females than males view these items as a "major part" of the scientific method. The wording in item 2G represents a composite view and therefore the students may have a vague conception that these processes fully describe the scientific method. Both groups agree on being accurate and not making errors (item 2H), while item 2E is the most important priority of the scientific method, i.e. to test and retest. This agrees with Parker's findings on item 2E.

A contemporary view held by many epistemologists is that there is no such thing as the scientific method (Aikenhead and Ryan, 1992b). The high percentage of "I don't know" responses to item 2K is not surprising if one considers that this view is not commonly expounded by teachers.

The items on **Scale Three** address the tentativeness of scientific knowledge, without actually mentioning the term "tentative" (Aikenhead and Ryan, 1992b). The Durban male and female students hold significantly different views as to why scientific knowledge changes. The highest c^2 value is recorded on item 3C, "scientific knowledge changes because the earth's physical environment changes". However, the main reason why scientific knowledge changes is because new scientists disprove the theories or discoveries of old scientists (item 3A).

The female students attribute a more important role to four of the items on Scale Three which examines the changing nature of technical and scientific knowledge. They believe more strongly than the males that:

- old facts become different facts (item 3A),
- old facts become the wrong facts (item 3B).
- external factors influence science and technology (item 3C),
- new facts are added onto old facts (item 3E).

However, this trend has to be interpreted with caution because, on Scales One, Two and Three taken as a whole, the female students are in stronger agreement than the males on 22 of the 26 items comprising the modified VOSTS instrument. One possible explanation for this disproportion may be that the female students as a whole may be less inclined to identify with "minority" views than perhaps their more "adventurous" male counterparts in the age range 15-17 years. Whether this a stable trend or not remains unknown.

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

The United Nations' Fourth Global Women's Conference in Beijing, September 1995, has highlighted the struggles of women in key areas such as health, education, environment, etc. Science and technology impact directly on all these sectors, and hence the contribution of women to these sectors can only be enhanced if science and engineering educators understand their views on science and technology.

Tamir (1994) has suggested that attitudes towards the scientific enterprise require knowledge and understanding of the scientific enterprise. The school, faculties of engineering, technikons, mass media and informal experiences all contribute to the development of these attitudes. The student's level of scientific and technological literacy is shaped by all these agencies which ultimately influence his or her views on science, technology and society.

The VOSTS instrument is different from conventional instruments which evaluate what a student is supposed to *know* about science, technology and society. It has a purported diagnostic function of monitoring student *perceptions* on STS topics. The data collected provide empirical evidence of student views on STS topics, but it does not yield normative scores (Aikenhead and Ryan, 1992a). The implication is that engineering curriculum developers and science educators may structure their courses and curricula partially according to the results from such a study, with the content of items 1F, 2B, 2E and 2H, by consensus, playing a role, at times in some schools, technikons and technical colleges.

In this study, significant sex differences were found on 15 of the 26 items on the modified VOSTS instrument. Student views about the extent to which certain factors contribute to the nature of science, the scientific method and the changing nature of scientific and technical knowledge also tend to be spread across a spectrum. These divergent views are also inconsistent with contemporary views of scienceand technology. The adoption of a STS approach by science and engineering educators might redress this and afford the students an opportunity to discuss the differences between science and technology.

In further studies, an analysis of the backgrounds of these students, together with allowing them to motivate their preferential responses, might possibly suggest underlying reasons for these differences. Differences, if any, between grade levels could also be determined. Furthermore, the fields of study which these students follow at tertiary level might also be traced to see how they relate to the observed differences on the modified VOSTS scales, as further investigations continue in Cape Town with samples of technikon and engineering undergraduates in 1997.

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TABLE 1: Student responses to each item on SCALE ONE ("Defining Science") of the modified VOSTS instrument for male students (N=498) and female students (N=499)

Defining what science is may be difficult. Indicate the part you think each statement below plays in describing science.

Science is:	Major Part		Minor Part		No Part		I Don't Know	
	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students
1A. inventing or designing things (e.g. artificial hearts, computers, space vehicles, etc.)	229	224	181	209	67	42	21	24
* 1B. finding cures for diseases and helping the environment	287	319	163	158	37	15	11	7
* 1C. explaining how things work	330	360	135	127	22	5	11	7
* 1D. bacteria, test tubes, beakers, chemicals, maths, etc.	207	281	206	189	51	24	34	5
* 1E. finding puzzles and solving them	165	225	208	218	99	38	26	18
* 1F. exploring the unkown and discovering something new about our world and universe	358	400	98	80	28	12	14	7
* 1G. making theories to explain things	311	365	147	116	21	8	19	10
1H. a body of knowledge and information based on facts	252	255	158	185	41	26	47	33
1I. a body of fundamental ideas, such as principles, laws and theories	287	299	152	148	26	11	33	41
* 1J. a study of new ideas about the world around us.	273	349	150	124	53	14	22	12

*$p<0.01$

TABLE 2: Student responses to each item on SCALE TWO ("The Scientific Method") of the modified VOSTS instrument for male students (N=498) and female students (N=499)

When scientists investigate, it is said that they follow "the scientific method". Indicate the part you think each statement below plays in describing the scientific method.

The scientific method is:	Major Part		Minor Part		No Part		I Don't Know	
	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students
2A. the lab procedures or techniques, often written in a book or journal, and usually by a scientist	226	257	148	141	23	11	101	90
* 2B. recording your results carefully	344	405	107	72	23	7	24	15
2C. controlling experimental variables carefully, leaving no room for interpretation	192	184	155	141	69	80	82	94
* 2D. getting facts, theories or hypotheses efficiently	316	370	118	89	21	5	43	35
* 2E. testing and re-testing, proving something true or false in a valid way	356	423	93	52	21	5	28	19
2F. postulating a theory then creating an experiment to prove it	272	307	132	117	41	25	53	50
* 2G. questioning, hypothesising, collecting data and concluding	300	379	131	73	24	5	43	42
2H. being accurate and not making errors	356	392	101	80	16	15	25	12
2I. a logical and widely accepted approach to solving problems	223	249	190	173	51	33	34	44
* 2J. an attitude that guides scientists their work	187	238	177	162	79	55	55	44
2K. considering what scientists actually do, there really is no such thing as the scientific method	56	41	85	76	156	161	201	221

*$p < 0.01$

TABLE 3: Student responses to each item on SCALE THREE ("Scientific Knowledge") of the modified VOSTS instrument for male students (N=498) and female students (N=499)

Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future. Indicate the part you think each statement below plays in describing how scientific knowledge changes								
Scientific knowledge:	Major Part		Minor Part		No Part		I Don't Know	
	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students	Male Students	Female Students
* 3A. changes because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" instrument	336	369	98	76	22	6	42	48
* 3B. changes because the old knowledge is re-interpreted in the light of new discoveries. Scientific facts can change	287	352	149	113	29	14	33	20
* 3C. changes because the earth's physical environment changes and this affects the outcome of investigations	162	212	206	204	93	49	37	34
3D. appears to change because the interpretation or the application of old facts can change. Correctly done experiments yield unchangeable facts	157	178	171	179	81	61	89	81
3E. appears to change because new knowledge is added onto old knowledge; the old knowledge doesn't change.	172	215	158	151	90	62	78	71

*$p < 0.01$

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V dňoch 22. - 24. 11. 1998 uskutoční sa v Stokholme, 10. výročná konferencia European Association for International Education.

Globálny svetový kongres o inžinierskom vzdelávaní

Globálny kongres o inžinierskom vzdelávaní (Global Congress on Engineering Education), ktorý sa uskutoční v dňoch 6. - 11. september 1998 na Akademii Gorniczo - Hutniczej v Krakove, Poľsko je vyvrcholením a spojením troch významných svetových tradičných akcií:

a, 5. svetovej konferencie o inžinierskom vzdelávaní.
b, 4. východno - západného kongresu o inžinierrskom vzdelávaní a
c, Medzinárodného kongresu leadrov priemyslu a univerzít - 1998.

Globálny kongres je doprovádzaný (počas roku 1997 a 1998) viacerými lokálnymi konferenciami, kongresami, seminármi v Európe, Afrike, Ázii, Austrálii (podrobnejšie pozri Senzor 1/97).

APPENDIX B

The modified VOSTS instrument

SCIENTIFIC METHOD **and** **THE NATURE OF SCIENCE AND SCIENTIFIC KNOWLEDGE**

1995

FACULTY OF ENGINEERING

Circle your year of study | 1 | 2 | 3 | 4 |

Circle your gender | F | M |

Circle your language | ENGLISH FIRST LANGUAGE | ENGLISH SECOND LANGUAGE |

If you wish, you may give your name or student number (but you do not have to)

THE OVERALL FINDINGS OF THIS STUDY WILL BE POSTED ON THE FACULTY OF ENGINEERING NOTICE BOARD FOR THE INTEREST OF YOUR GROUP

Defining what science is may be difficult. ***Indicate the part you think each statement below plays in describing science by circling the appropriate code number:***

4	*major part*
3	*minor part*
2	*no part*
1	*I don't know*

Science is:

1.	inventing or designing things (e.g. artificial hearts, computers, space vehicles, etc.)	4	3	2	1
2.	finding cures for diseases and helping the environment	4	3	2	1
3.	explaining how things work	4	3	2	1
4.	bacteria, test tubes, beakers, chemicals, maths, etc.	4	3	2	1
5.	finding puzzles and solving them	4	3	2	1
6.	exploring the unknown and discovering something new about our world and universe	4	3	2	1
7.	making theories to explain things	4	3	2	1
8.	a body of knowledge and information based on facts	4	3	2	1
9.	a body of fundamental ideas, such as principles, laws and theories	4	3	2	1
10.	a study of new ideas about the world around us	4	3	2	1

When scientists investigate, it is said that they follow "the scientific method". ***Indicate the part you think each statement below plays in describing the scientific method by circling the appropriate code number:***

4 major part
3 minor part
2 no part
1 I don't know

The scientific method is:

1.	the lab procedures or techniques, often written in a book or journal and usually used by a scientist	4	3	2	1
2.	recording your results carefully	4	3	2	1
3.	controlling experimental variables carefully, leaving no room for interpretation	4	3	2	1
4.	getting facts, theories or hypotheses efficiently	4	3	2	1
5.	testing and retesting - proving something true or false in a valid way	4	3	2	1
6.	postulating a theory then creating an experiment to prove it	4	3	2	1
7.	questioning, hypothesising, collecting data and concluding	4	3	2	1
8.	being accurate and not making errors	4	3	2	1
9.	a logical and widely accepted approach to solving problems	4	3	2	1
10.	an attitude that guides scientists in their work	4	3	2	1
11.	considering what scientists actually do, there really is no such thing as the scientific method	4	3	2	1

Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.
Indicate the part you think each statement below plays in describing how scientific knowledge changes by circling the appropriate code number:

4 major part
3 minor part
2 no part
1 I don't know

Scientific knowledge:

1.	changes because new scientists *disprove* the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation	4	3	2	1
2.	changes because the old knowledge is *reinterpreted* in light of new discoveries. Scientific facts can change.	4	3	2	1
3.	changes because the earth's physical environment changes and this affects the outcome of investigations	4	3	2	1
4.	appears to change because the *interpretation* or the application of old facts can change. Correctly performed experiments yield unchangeable facts	4	3	2	1
5.	appears to change because new knowledge is *added onto* old knowledge; the old knowledge doesn't change	4	3	2	1

APPENDIX C

"Traditional" and "contemporary" models of the nature of science

Appendix 2: Contemporary Model of the Nature of Science

Theory (T)

1. Observations are theory laden.
2. Theories are the inventions of scientists.
3. The occurrence of a contradictory fact does not necessarily compel the abandonment of a theory.
4. Theories are tools used to describe, explain, and predict scientific phenomena.
5. Theories fit within certain paradigms.

6.1. A scientist's initial notions of where to start an inquiry are theory laden.
6.2. Theories are validated by their connection to other, generally accepted theories.
6.3. Observations are influenced by social factors.

What a Scientist Does (S)

1. The primary act of a scientist is often a leap of imagination or creativity.
2. A scientist interprets results based on prior knowledge, observation, logic, and social factors.
3. Scientists create theories based on prior knowledge, observation, and logic.
4. A scientist works within the scientific community to evaluate and contemplate the work of other scientists.

5.1. Scientists make decisions before inquiry based on prior knowledge, observation, logic, and social factors.
5.2. A scientist is someone who is curious.
5.3. Scientists communicate with other members of the community.
5.4. A scientist is influenced by past research.
5.5. The first inclination of a scientist is to try and integrate new knowledge into old knowledge.

Scientific Knowledge (K)

1. The progression of scientific knowledge is not continuous.
2. Scientific knowledge is tentative.
3. Scientific knowledge is created and validated by common acceptance within the scientific community.
4. Scientists create knowledge based on prior knowledge, observation, and logic.

5.1. The tentativeness of knowledge is related to how much people work on it.
5.2. The truth is defined as an accurate description of nature.

Scientific Method (M)

1. Scientists are not compelled to use the traditional scientific method.
2. There is no single scientific method.
3. Methods used by scientists depend on circumstances.

4.1. Knowledge can be gained by means other than the scientific method.
4.2. Scientists can adjust their method of inquiry in the middle of an investigation and still obtain valid results.
4.3. The traditional scientific method is simply one possible guide for inquiry.

Laws (L)

1. Laws are created by scientists.
2. Laws are validated within the scientific community.
3. Laws are a scientist's best attempt to explain some part of nature.

General (G)

1. Science is an organization of our knowledge to help us learn about nature.
2. Science is part of human progress and creativity. (Science is life.)
3. Science is a search for findings. (Science is a process.)
4. Science consists of many disciplines and processes.

5.1. Science is a competitive enterprise.
5.2. The popularity of scientific knowledge is directly related to the prestige of the people who originated that knowledge.
5.3. The ease with which a scientist accepts knowledge is directly related to how close the scientist's paradigm (research program, etc.) and the knowledge paradigm are to each other.

APPENDIX D

Raw scores of first-year college of education students

COLLEGE OF EDUCATION STUDENTS' RAW SCORES ON THE VOSTS INSTRUMENT

ITEM NUMBER

SEX	YEAR	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	2A	2B	2C	2D	2E	2F	2G	2H	2I	2J	2K	3A	3B	3C	3D	3E	TOT
M	1	4	4	4	4	3	4	4	3	4	4	4	4	4	4	4	3	3	3	3	4	4	3	4	4	3	3	95
M	1	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	3	4	99
M	1	4	4	2	2	3	4	3	2	3	4	3	4	4	3	4	4	4	4	4	3	4	4	3	4	4	4	91
M	1	4	4	4	4	2	3	4	3	3	3	4	4	3	3	4	2	4	4	3	3	3	3	1	4	4	4	87
M	1	4	4	3	3	3	3	3	1	3	1	4	3	1	4	3	1	3	4	3	3	2	3	3	4	3	4	76
M	1	4	4	3	3	4	4	4	3	2	4	4	3	3	2	4	4	3	4	4	4	4	3	3	4	3	4	91
M	1	2	4	4	2	4	4	3	4	1	3	1	2	3	2	4	3	4	1	2	4	4	2	4	4	3	1	75
M	1	4	4	4	3	2	4	4	4	3	4	3	3	4	4	2	3	4	2	3	2	4	4	4	4	3	4	89
M	1	4	4	4	4	3	4	4	4	3	4	1	4	4	4	4	1	4	1	1	4	1	1	4	3	1	1	77
M	1	4	4	4	4	3	4	3	3	1	3	4	4	3	4	4	4	4	4	4	3	1	3	1	3	2	1	82
M	1	3	4	2	4	2	4	4	2	2	4	4	4	3	4	4	4	2	2	1	2	2	4	4	3	1	1	76
M	1	3	3	2	2	3	2	1	2	3	2	4	3	2	3	2	2	2	1	1	3	2	4	3	2	3	2	62
M	1	4	4	4	4	3	4	4	3	3	3	3	4	1	3	3	1	4	4	4	4	1	4	4	4	4	4	88
F	1	4	4	4	4	3	4	4	4	4	4	4	4	2	4	4	3	4	4	4	4	2	4	4	3	3	4	96
F	1	3	4	4	3	1	4	4	3	4	4	3	4	4	3	4	1	4	4	4	1	2	4	3	3	1	4	83
F	1	4	4	4	4	3	3	3	4	3	4	2	3	4	3	4	2	4	3	3	4	1	4	3	2	1	3	82
F	1	4	4	3	3	4	4	3	2	3	4	4	4	3	1	4	4	4	2	3	4	1	4	4	4	4	3	87
F	1	4	4	4	4	4	4	4	4	4	3	4	4	2	4	4	4	4	3	3	3	1	3	3	4	1	4	90
F	1	4	4	4	3	3	4	4	4	4	3	4	4	3	4	4	3	4	4	4	3	1	4	3	3	4	4	93
F	1	3	3	4	4	3	4	4	4	3	4	4	4	3	4	4	4	4	3	3	4	4	4	3	3	4	4	95
F	1	4	4	4	4	4	4	4	4	4	4	4	4	1	4	4	4	4	4	4	4	1	4	4	4	1	1	92
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F	1	3	3	4	4	2	4	4	4	3	1	3	4	3	1	4	4	4	3	2	3	4	4	4	3	3	4	85
F	1	3	3	3	3	3	4	3	4	4	4	3	1	2	3	4	4	4	2	2	2	4	3	4	3	4	4	83
F	1	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	3	3	4	4	3	3	3	98
F	1	3	4	4	4	4	4	3	4	4	4	3	4	4	4	4	4	4	4	3	4	4	4	4	4	3	4	99
F	1	4	4	3	3	3	3	3	3	4	3	3	4	1	4	4	3	4	2	4	2	2	2	3	4	4	3	82
F	1	4	3	4	4	1	4	4	3	4	4	4	4	1	4	4	4	4	4	4	3	4	4	3	4	4	3	93
F	1	4	4	3	4	3	4	4	3	4	4	4	4	1	4	4	4	4	4	3	4	1	4	4	4	2	2	90
F	1	2	2	3	3	3	4	3	2	4	2	3	2	2	3	4	3	3	2	1	2	4	4	4	4	2	1	72
F	1	4	4	3	3	3	4	4	3	3	4	3	4	3	4	4	4	4	3	4	4	4	4	4	4	4	4	96
F	1	4	3	4	4	4	4	4	4	4	4	4	4	3	4	4	4	3	4	3	4	4	4	4	4	3	4	99
F	1	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	3	4	4	3	3	4	3	4	3	4	98
F	1	3	4	1	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1	4	4	4	4	4	96

DATA USED TO CALCULATE THE CRONBACH ALPHA RELIABILITY COEFFICIENT FOR THE VOSTS SCALES

F	1	4	4	4	2	4	4	4	4	4	4	4	4	3	4	4	4	4	3	3	4	4	4	4	4	4	4	99
F	1	4	4	3	4	1	4	4	1	1	3	4	4	4	1	1	4	4	2	4	4	1	4	3	4	4	4	81
F	1	2	3	4	4	3	2	3	2	4	2	4	4	2	3	4	4	3	2	3	4	3	2	3	2	4	3	79
F	1	4	3	3	3	2	4	4	3	3	4	4	3	2	3	2	4	2	3	3	4	3	2	3	3	3	4	81
F	1	3	4	4	4	3	4	4	3	3	4	3	3	2	1	1	2	3	4	2	4	3	4	4	4	3	2	81
F	1	4	4	4	2	2	3	3	3	3	3	2	3	4	1	1	3	3	3	4	4	4	4	2	3	4	2	78
F	1	4	3	3	3	3	2	2	3	2	3	3	3	2	3	3	3	2	3	3	4	4	4	3	4	3	4	79
F	1	3	4	4	4	4	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	2	4	4	4	4	1	96
F	1	2	4	3	4	2	1	2	3	2	2	4	2	3	3	4	2	4	4	2	3	2	4	4	3	3	3	75
F	1	4	4	4	4	3	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	2	4	4	4	4	4	99
F	1	4	4	3	4	2	4	4	2	3	4	4	4	3	1	4	4	3	2	3	4	1	2	4	3	3	4	83
F	1	4	4	4	2	4	4	4	4	4	4	4	4	3	4	4	4	4	3	3	4	4	4	4	4	4	4	99
ITEM MEAN		3.59	3.76	3.50	3.43	2.98	3.70	3.57	3.22	3.26	3.48	3.50	3.57	2.78	3.24	3.61	3.33	3.59	3.15	3.15	3.46	2.63	3.57	3.46	3.57	3.07	3.17	87.30
ITEM SD		0.65	0.47	0.71	0.71	0.85	0.69	0.68	0.86	0.87	0.83	0.77	0.71	0.95	1.03	0.87	0.98	0.65	0.95	0.93	0.77	1.22	0.77	0.74	0.61	0.99	1.11	21.38
ITEM VAR		0.42	0.23	0.51	0.51	0.72	0.47	0.46	0.74	0.76	0.68	0.60	0.51	0.91	1.05	0.76	0.96	0.42	0.91	0.87	0.60	1.49	0.59	0.55	0.38	0.97	1.23	18.29

TOTAL S 78.99

APPENDIX E

Chi-square statistics and Z-scores

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
1.59919	3	0.659574

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00148	0.00313	0.00000
Uncertainty Coeff.	0.00140	0.00176	0.00116
Somer's D	0.03843	0.03510	0.04244

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
[illegible]	3	0.919701

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00532	0.00938	0.00000
Uncertainty Coeff.	0.00049	0.00054	0.00044
Somer's D	-0.00753	-0.00751	-0.00756

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
5.11551	3	0.163532

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03486	0.05938	0.00000
Uncertainty Coeff.	0.00517	0.00561	0.00480
Somer's D	-0.06489	-0.06634	-0.06349

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
4.14756	3	0.245865

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01976	0.04063	0.00000
Uncertainty Coeff.	0.00370	0.00456	0.00311
Somer's D	-0.03268	-0.03022	-0.03558

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
8.24942	3	0.0411285

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01835	0.04063	0.00000
Uncertainty Coeff.	0.00715	0.00931	0.00580
Somer's D	-0.06438	-0.05776	-0.07271

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
5.62437	3	0.131386

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.02648	0.04063	0.00000
Uncertainty Coeff.	0.00598	0.00626	0.00573
Somer's D	-0.05692	-0.06312	-0.05184

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
6.26254	3	0.0995128

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01498	0.02500	0.00000
Uncertainty Coeff.	0.00645	0.00704	0.00596
Somer's D	0.00101	0.00105	0.00098

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
10.4939	3	0.0148023

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.02782	0.05625	0.00000
Uncertainty Coeff.	0.00906	0.01164	0.00741
Somer's D	-0.00571	-0.00519	-0.00634

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
19.5814	3	2.07258E-4

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04992	0.09375	0.00000
Uncertainty Coeff.	0.01822	0.02220	0.01546
Somer's D	-0.13094	-0.12351	-0.13832

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
1.64396	3	0.649464

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01075	0.01875	0.00000
Uncertainty Coeff.	0.00155	0.00180	0.00137
Somer's D	-0.04287	-0.04230	-0.04346

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
9.30791	3	0.0254652

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03561	0.07500	0.00000
Uncertainty Coeff.	0.00765	0.01022	0.00611
Somer's D	-0.09722	-0.08583	-0.11210

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
3.54962	3	0.314383

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03055	0.04688	0.00000
Uncertainty Coeff.	0.00368	0.00388	0.00350
Somer's D	-0.06418	-0.07091	-0.05861

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
15.2715	3	1.59874E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04658	0.10625	0.00000
Uncertainty Coeff.	0.01161	0.01685	0.00886
Somer's D	-0.10384	-0.08815	-0.12632

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
2.86033	3	0.413665

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01873	0.03125	0.00000
Uncertainty Coeff.	0.00272	0.00314	0.00241
Somer's D	-0.03380	-0.03408	-0.03352

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
4.85071	3	0.183061

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.02350	0.03438	0.00000
Uncertainty Coeff.	0.00531	0.00544	0.00519
Somer's D	-0.04865	-0.05688	-0.04251

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
1.64582	3	0.649045

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01184	0.02168	0.00000
Uncertainty Coeff.	0.00143	0.00180	0.00113
Somer's D	-0.01534	[illegible]	[illegible]

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
7.33215	3	0.0620317

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04745	0.08125	0.00000
Uncertainty Coeff.	0.00681	0.00803	0.00591
Somer's D	-0.09081	-0.08957	-0.09210

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
3.16173	3	0.367355

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01681	0.02500	0.00000
Uncertainty Coeff.	0.00343	0.00352	0.00334
Somer's D	-0.02125	-0.02441	-0.01882

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
1.12192	3	0.771784

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00750	0.01563	0.00000
Uncertainty Coeff.	0.00095	0.00123	0.00077
Somer's D	-0.01656	-0.01496	-0.01854

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
3.67339	3	0.298960

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01447	0.03125	0.00000
Uncertainty Coeff.	0.00292	0.00403	0.00229
Somer's D	0.01410	0.01232	0.01648

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
8.99591	3	0.0293453

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03414	0.07500	0.00000
Uncertainty Coeff.	0.00702	0.00990	0.00543
Somer's D	-0.08098	-0.06980	-0.09642

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
6.05402	3	0.109012

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03396	0.05625	0.00000
Uncertainty Coeff.	0.00578	0.00666	0.00511
Somer's D	-0.06461	-0.06544	-0.06380

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
4.21539	3	0.239126

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.02456	0.04375	0.00000
Uncertainty Coeff.	0.00390	0.00463	0.00337
Somer's D	-0.07119	-0.06906	-0.07346

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
1.80339	3	0.614199

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00288	0.00625	0.00000
Uncertainty Coeff.	0.00148	[illegible]	[illegible]
Somer's D	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	Significance
12.2446	3	6.58066E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03877	0.08438	0.00467
Uncertainty Coeff.	0.00933	0.01349	0.00713
Somer's D	-0.06446	-0.05482	-0.07823

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
3.61462	3	0.306197

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01934	0.04375	0.00000
Uncertainty Coeff.	0.00276	0.00396	0.00211
Somer's D	0.01464	0.01250	0.01767

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
15.2876	3	1.58666E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01644	0.03438	0.00000
Uncertainty Coeff.	0.01217	0.01484	0.01031
Somer's D	-0.09567	-0.08895	-0.10350

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
36.9521	3	4.71012E-8

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.08253	0.13438	0.00000
Uncertainty Coeff.	0.03395	0.03571	0.03237
Somer's D	-0.19013	-0.20684	-0.17593

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
25.5010	3	1.21302E-5

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.05124	0.02813	0.07163
Uncertainty Coeff.	0.02157	0.02502	0.01895
Somer's D	0.17078	0.16163	0.18103

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
9.86167	3	0.0197793

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04378	0.01250	0.06813
Uncertainty Coeff.	0.00760	0.00960	0.00630
Somer's D	0.05257	0.04777	0.05845

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
47.0067	3	3.46415E-10

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04845	0.11250	0.00000
Uncertainty Coeff.	0.03311	0.04678	0.02562
Somer's D	0.22289	0.19173	0.26643

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
2.23769	3	0.524563

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00574	0.00838	0.00000
Uncertainty Coeff.	0.00200	0.00215	0.00187
Somer's D	-0.02838	-0.03055	-0.02650

Appendix 1: Traditional Model of the Nature of Science

Theory (T)

1. Theories are based directly on observation.
2. New theories are improvements over old theories because observations improve and increase over time.
3. An entire theory is falsified if subject to a single contradictory fact.
4. A theory is a hypothesis that has been proven to be correct.
5. Old theories are of no use to scientists.

Role of a Scientist (S)

1. A scientist evaluates scientific claims exclusively through empirical evidence.
2. All actions of a scientist are assumed to be open-minded and objective.
3. A scientist is someone who uses the traditional scientific method.
4. A scientist strives to discover the absolute truth.

5.1. Scientists must avoid being influenced by anything outside of "pure" science.

5.2. Scientists must report data exactly as their senses perceive it.

Scientific Knowledge (K)

1. Scientific knowledge corresponds directly to reality.
2. Scientific knowledge increases by accretion from observations.
3. Scientific knowledge progresses by an accumulation of observations.
4. Scientific knowledge is proven or disproven owing to the direct influence of observations.

5.1. Scientific knowledge is unchanging.

5.2. Scientific data must not be interpreted by the scientist.

Scientific Method (M)

1. Science relies on precise control of experiments (and match with prediction) for proof.
2. The use of the traditional scientific method is necessary to discover and validate theories.
3. There is a single method for doing science.
4. The scientific method is a step-by-step process.

5.1. The method must be planned out in advance of the inquiry.

5.2. When a scientist uses the traditional scientific method correctly, the results are true without doubt.

Laws (L)

1. Scientific laws are found directly in nature.
2. Scientists interpret the laws found in nature.
3. Scientific laws can be proven to be absolutely true.
4. Laws are proven theories.

General (G)

1. Science is only the set of findings called scientific knowledge.
2. Explaining an event consists of carefully reducing that event to known knowledge.
3. Progress consists of discovering theories that represent a closer approximation to the absolute truth.

4.1. Science is "doing experiments."

4.2. The goal of science is to find the absolute truth.

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
30.7096	3	9.78539E-7

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.01387	0.02813	0.00000
Uncertainty Coeff.	0.02541	0.03046	0.02179
Somer's D	0.18715	0.17609	0.19970

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
5.85635	3	0.118812

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00425	0.00570	0.00339
Somer's D	0.07893	0.06959	0.09115

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
14.0428	3	2.84751E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.01028	0.01339	0.00812
Somer's D	0.10477	0.09171	0.12216

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
13.2897	3	4.05031E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.01073	0.01333	0.00898
Somer's D	0.09156	0.08514	0.09902

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
21.0966	3	1.00524E-4

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.04293	0.00000	0.07203
Uncertainty Coeff.	0.01508	0.02113	0.01172
Somer's D	0.04468	0.03830	0.05360

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
20.4002	3	1.40223E-4

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00672	0.01250	0.00000
Uncertainty Coeff.	0.01747	0.02024	0.01537
Somer's D	0.11559	0.11310	0.11820

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
31.1198	3	8.02096E-7

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.02463	0.03124	0.02032
Somer's D	0.13742	0.12618	0.15064

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
16.5431	3	8.77346E-4

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.01402	0.01645	0.01221
Somer's D	0.13015	0.12981	0.13049

Summary Statistics for Contingency Tables (Page 1)

Chi-square	[illegible]	Significance
16.2733	3	[illegible]

[illegible]	[illegible]	[illegible] dependent	[illegible] columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.01215	0.01604	0.00978
Somer's D	0.07756	0.06936	0.08795

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
23.2049	3	3.66007E-5

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.01767	0.02337	0.01421
Somer's D	0.13446	0.12010	0.15273

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
53.2258	3	1.64092E-11

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03268	0.06250	0.00000
Uncertainty Coeff.	0.04505	0.05602	0.03766
Somer's D	0.24134	0.22740	0.25710

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
16.8154	3	7.71278E-4

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.03553	0.00313	0.05909
Uncertainty Coeff.	0.01226	0.01671	0.00968
Somer's D	0.12704	0.11104	0.14842

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
34.6887	3	1.41673E-7

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.10566	0.10625	0.10526
Uncertainty Coeff.	0.02338	0.03381	0.01786
Somer's D	0.16817	0.14248	0.20515

[illegible]

Chi-square	D.F.	Significance
[illegible]	[illegible]	[illegible]

Statistic	Symmetric	With rows dependent	With columns dependent
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
3.86325	3	0.276614

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00266	0.00379	0.00205
Somer's D	-0.05224	-0.04473	-0.06279

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
7.24996	3	0.0643435

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00564	0.00710	0.00467
Somer's D	0.08729	0.08117	0.09440

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
22.7659	3	4.51638E-5

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00852	0.01875	0.00000
Uncertainty Coeff.	0.01683	0.02242	[illegible]
Somer's D	0.162[illegible]	[illegible]	[illegible]

[illegible]

Chi-square	[illegible]	[illegible]
11.9530	3	7.54603E-3

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00863	0.01209	0.00671
Somer's D	0.08733	0.07528	0.10397

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
5.12898	3	0.162593

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00339	0.00496	0.00258
Somer's D	0.06322	0.05317	0.07795

Summary Statistics for Contingency Tables (Page 1)

Chi-square	D.F.	Significance
4.87771	3	0.180874

Statistic	Symmetric	With rows dependent	With columns dependent
Lambda	0.00000	0.00000	0.00000
Uncertainty Coeff.	0.00328	0.00479	0.00249
Somer's D	0.06900	0.05812	0.08488

Comparison of Two Samples

Sample 1: STD10.var2

Sample 2: PENTECH.var4

Test: Unpaired

Average rank of first group = 206.362 based on 340 values.
Average rank of second group = 281.602 based on 108 values.
Large sample test statistic Z = 5.85948
Two-tailed probability of equaling or exceeding Z = 4.65834E-9

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var3

Sample 2: PENTECH.var5

Test: Unpaired

Average rank of first group = 223.306 based on 340 values.
Average rank of second group = 228.259 based on 108 values.
Large sample test statistic Z = 0.410589
Two-tailed probability of equaling or exceeding Z = 0.681371

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var4

Sample 2: PENTECH.var6

Test: Unpaired

Average rank of first group = 229.841 based on 340 values.
Average rank of second group = 207.685 based on 108 values.
Large sample test statistic Z = -1.8777
Two-tailed probability of equaling or exceeding Z = 0.0604213

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var5

Sample 2: PENTECH.var7

Test: Unpaired

Average rank of first group = 231.918 based on 340 values.
Average rank of second group = 201.148 based on 108 values.
Large sample test statistic Z = -2.37885
Two-tailed probability of equaling or exceeding Z = 0.0173666

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var6

Sample 2: PENTECH.var8

Test: Unpaired

Average rank of first group = 237.674 based on 340 values.
Average rank of second group = 183.028 based on 108 values.
Large sample test statistic Z = -4.10433
Two-tailed probability of equaling or exceeding Z = 4.05717E-5

NOTE: 448 total observations.

Comparison of Two Samples
Comparison of Two Samples

Sample 1: STD10.var7

Sample 2: PENTECH.var9

Test: Unpaired

Average rank of first group = 222.026 based on 340 values.
Average rank of second group = 232.287 based on 108 values.
Large sample test statistic Z = 0.985337
Two-tailed probability of equaling or exceeding Z = 0.324457

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var8

Sample 2: PENTECH:var10

Test: Unpaired

Average rank of first group = 229.149 based on 340 values.
Average rank of second group = 209.866 based on 108 values.
Large sample test statistic Z = -1.61475
Two-tailed probability of equaling or exceeding Z = 0.106366

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var9

Sample 2: PENTECH.var11

Test: Unpaired

Average rank of first group = 228.538 based on 340 values.
Average rank of second group = 211.787 based on 108 values.
Large sample test statistic Z = -1.28431
Two-tailed probability of equaling or exceeding Z = 0.199031

NOTE: 448 total observations.

Comparison of Two Samples

Comparison of Two Samples

Sample 1: STD10.var10

Sample 2: PENTECH.var12

Test: Unpaired

Average rank of first group = 224.419 based on 340 values.
Average rank of second group = 224.755 based on 108 values.
Large sample test statistic Z = 0.0270494
Two-tailed probability of equaling or exceeding Z = 0.978415

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var11

Sample 2: PENTECH.var13

Test: Unpaired

Average rank of first group = 228.732 based on 340 values.
Average rank of second group = 211.176 based on 108 values.
Large sample test statistic Z = -1.44891
Two-tailed probability of equaling or exceeding Z = 0.147361

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var12

Sample 2: PENTECH.var14

Test: Unpaired

Average rank of first group = 222.815 based on 340 values.
Average rank of second group = 229.806 based on 108 values.
Large sample test statistic Z = 0.533528
Two-tailed probability of equaling or exceeding Z = 0.593665

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var13

Sample 2: PENTECH.var15

Test: Unpaired

Average rank of first group = 230.897 based on 340 values.
Average rank of second group = 204.361 based on 108 values.
Large sample test statistic Z = -2.42181
Two-tailed probability of equaling or exceeding Z = 0.0154433

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var14

Sample 2: PENTECH.var16

Test: Unpaired

Average rank of first group = 229.878 based on 340 values.
Average rank of second group = 207.569 based on 108 values.
Large sample test statistic Z = -1.64154
Two-tailed probability of equaling or exceeding Z = 0.100685

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var15

Sample 2: PENTECH.var17

Test: Unpaired

Average rank of first group = 230.234 based on 340 values.
Average rank of second group = 206.449 based on 108 values.
Large sample test statistic Z = -1.99108
Two-tailed probability of equaling or exceeding Z = 0.0464719

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var16

Sample 2: PENTECH.var18

Test: Unpaired

Average rank of first group = 225.11 based on 340 values.
Average rank of second group = 222.579 based on 108 values.
Large sample test statistic Z = -0.249021
Two-tailed probability of equaling or exceeding Z = 0.80334

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var17

Sample 2: PENTECH.var19

Test: Unpaired

Average rank of first group = 219.309 based on 340 values.
Average rank of second group = 240.843 based on 108 values.
Large sample test statistic Z = 1.73426
Two-tailed probability of equaling or exceeding Z = 0.0828725

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var18

Sample 2: PENTECH.var20

Test: Unpaired

Average rank of first group = 238.926 based on 340 values.
Average rank of second group = 179.083 based on 108 values.
Large sample test statistic Z = -4.87714
Two-tailed probability of equaling or exceeding Z = 1.07788E-6

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var19

Sample 2: PENTECH.var21

Test: Unpaired

Average rank of first group = 245.872 based on 340 values.
Average rank of second group = 157.218 based on 108 values.
Large sample test statistic Z = -7.53521
Two-tailed probability of equaling or exceeding Z = 4.92939E-14

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var20

Sample 2: PENTECH.var22

Test: Unpaired

Average rank of first group = 221.078 based on 340 values.
Average rank of second group = 235.273 based on 108 values.
Large sample test statistic Z = 1.08524
Two-tailed probability of equaling or exceeding Z = 0.277812

NOTE: 448 total observations.

Comparison of Two Samples
Comparison of Two Samples

Sample 1: STD10.var21

Sample 2: PENTECH.var23

Test: Unpaired

Average rank of first group = 226.088 based on 340 values.
Average rank of second group = 219.5 based on 108 values.
Large sample test statistic Z = -0.491571
Two-tailed probability of equaling or exceeding Z = 0.62302

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var22

Sample 2: PENTECH.var24

Test: Unpaired

Average rank of first group = 221.89 based on 340 values.
Average rank of second group = 232.718 based on 108 values.
Large sample test statistic Z = 0.796292
Two-tailed probability of equaling or exceeding Z = 0.42586

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var23

Sample 2: PENTECH.var25

Test: Unpaired

Average rank of first group = 228.335 based on 340 values.
Average rank of second group = 212.426 based on 108 values.
Large sample test statistic Z = -1.36406
Two-tailed probability of equaling or exceeding Z = 0.172547

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var24

Sample 2: PENTECH.var26

Test: Unpaired

Average rank of first group = 231.924 based on 340 values.
Average rank of second group = 201.13 based on 108 values.
Large sample test statistic Z = -2.50688
Two-tailed probability of equaling or exceeding Z = 0.0121801

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var25

Sample 2: PENTECH.var27

Test: Unpaired

Average rank of first group = 234.888 based on 340 values.
Average rank of second group = 191.796 based on 108 values.
Large sample test statistic Z = -3.21428
Two-tailed probability of equaling or exceeding Z = 1.30783E-3

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var26

Sample 2: PENTECH.var28

Test: Unpaired

Average rank of first group = 223.334 based on 340 values.
Average rank of second group = 228.171 based on 108 values.
Large sample test statistic Z = 0.355396
Two-tailed probability of equaling or exceeding Z = 0.72229

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var27

Sample 2: PENTECH.var29

Test: Unpaired

Average rank of first group = 215.61 based on 340 values.
Average rank of second group = 252.486 based on 108 values.
Large sample test statistic Z = 2.72375
Two-tailed probability of equaling or exceeding Z = 6.45459E-3

NOTE: 448 total observations.

Comparison of Two Samples

Sample 1: STD10.var2

Sample 2: HEWAT.var2

Test: Unpaired

Average rank of first group = 191.612 based on 340 values.
Average rank of second group = 237.491 based on 55 values.
Large sample test statistic Z = 3.03796
Two-tailed probability of equaling or exceeding Z = 2.38198E-3

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var3

Sample 2: HEWAT.var3

Test: Unpaired

Average rank of first group = 193.766 based on 340 values.
Average rank of second group = 224.173 based on 55 values.
Large sample test statistic Z = 2.19894
Two-tailed probability of equaling or exceeding Z = 0.027882

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var4

Sample 2: HEWAT.var4

Test: Unpaired

Average rank of first group = 199.172 based on 340 values.
Average rank of second group = 190.755 based on 55 values.
Large sample test statistic Z = -0.624222
Two-tailed probability of equaling or exceeding Z = 0.532479

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var5

Sample 2: HEWAT.var5

Test: Unpaired

Average rank of first group = 197.846 based on 340 values.
Average rank of second group = 198.955 based on 55 values.
Large sample test statistic Z = 0.0737268
Two-tailed probability of equaling or exceeding Z = 0.941222

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var6

Sample 2: HEWAT.var6

Test: Unpaired

Average rank of first group = 204.147 based on 340 values.
Average rank of second group = 160 based on 55 values.
Large sample test statistic Z = -2.88767
Two-tailed probability of equaling or exceeding Z = 3.88125E-3

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var7

Sample 2: HEWAT.var7

Test: Unpaired

Average rank of first group = 196.231 based on 340 values.
Average rank of second group = 208.936 based on 55 values.
Large sample test statistic Z = 1.0474
Two-tailed probability of equaling or exceeding Z = 0.294915

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var8

Sample 2: HEWAT.var8

Test: Unpaired

Average rank of first group = 198.19 based on 340 values.
Average rank of second group = 196.827 based on 55 values.
Large sample test statistic Z = -0.0991869
Two-tailed probability of equaling or exceeding Z = 0.920985

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var9

Sample 2: HEWAT.var9

Test: Unpaired

Average rank of first group = 197.232 based on 340 values.
Average rank of second group = 202.745 based on 55 values.
Large sample test statistic Z = 0.365563
Two-tailed probability of equaling or exceeding Z = 0.714688

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var10

Sample 2: HEWAT.var10

Test: Unpaired

Average rank of first group = 201.124 based on 340 values.
Average rank of second group = 178.691 based on 55 values.
Large sample test statistic Z = -1.5711
Two-tailed probability of equaling or exceeding Z = 0.11616

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var11

Sample 2: HEWAT.var11

Test: Unpaired

Average rank of first group = 199.922 based on 340 values.
Average rank of second group = 186.118 based on 55 values.
Large sample test statistic Z = -0.990124
Two-tailed probability of equaling or exceeding Z = 0.322112

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var12

Sample 2: HEWAT.var12

Test: Unpaired

Average rank of first group = 194.556 based on 340 values.
Average rank of second group = 219.291 based on 55 values.
Large sample test statistic Z = 1.63464
Two-tailed probability of equaling or exceeding Z = 0.102124

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var13

Sample 2: HEWAT.var13

Test: Unpaired

Average rank of first group = 199.64 based on 340 values.
Average rank of second group = 187.864 based on 55 values.
Large sample test statistic Z = -0.953709
Two-tailed probability of equaling or exceeding Z = 0.340229

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var14

Sample 2: HEWAT.var14

Test: Unpaired

Average rank of first group = 199.11 based on 340 values.
Average rank of second group = 191.136 based on 55 values.
Large sample test statistic Z = -0.507098
Two-tailed probability of equaling or exceeding Z = 0.612083

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var15

Sample 2: HEWAT.var15

Test: Unpaired

Average rank of first group = 202.413 based on 340 values.
Average rank of second group = 170.718 based on 55 values.
Large sample test statistic Z = -2.29737
Two-tailed probability of equaling or exceeding Z = 0.0215977

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var16

Sample 2: HEWAT.var16

Test: Unpaired

Average rank of first group = 197.618 based on 340 values.
Average rank of second group = 200.364 based on 55 values.
Large sample test statistic Z = 0.235456
Two-tailed probability of equaling or exceeding Z = 0.813851

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var17

Sample 2: HEWAT.var17

Test: Unpaired

Average rank of first group = 196.944 based on 340 values.
Average rank of second group = 204.527 based on 55 values.
Large sample test statistic Z = 0.52043
Two-tailed probability of equaling or exceeding Z = 0.602761

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var18

Sample 2: HEWAT.var18

Test: Unpaired

Average rank of first group = 197.819 based on 340 values.
Average rank of second group = 199.118 based on 55 values.
Large sample test statistic Z = 0.0961975
Two-tailed probability of equaling or exceeding Z = 0.923358

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var19

Sample 2: HEWAT.var19

Test: Unpaired

Average rank of first group = 205.141 based on 340 values.
Average rank of second group = 153.855 based on 55 values.
Large sample test statistic Z = -4.02053
Two-tailed probability of equaling or exceeding Z = 5.8095E-5

NOTE: 395 total observations.

```
                    Comparison of Two Samples
----------------------------------------------------------------
Sample 1: STD10.var20

Sample 2: HEWAT.var20

Test: Unpaired

Average rank of first group = 197.896 based on 340 values.
Average rank of second group = 198.645 based on 55 values.
Large sample test statistic Z = 0.0485027
Two-tailed probability of equaling or exceeding Z = 0.96131

NOTE:  395 total observations.
```

```
                    Comparison of Two Samples
----------------------------------------------------------------
Sample 1: STD10.var21

Sample 2: HEWAT.var21

Test: Unpaired

Average rank of first group = 191.862 based on 340 values.
Average rank of second group = 235.945 based on 55 values.
Large sample test statistic Z = 2.85894
Two-tailed probability of equaling or exceeding Z = 4.25073E-3

NOTE:  395 total observations.
```

```
                    Comparison of Two Samples
----------------------------------------------------------------
Sample 1: STD10.var22

Sample 2: HEWAT.var22

Test: Unpaired

Average rank of first group = 191.744 based on 340 values.
Average rank of second group = 236.673 based on 55 values.
Large sample test statistic Z = 2.83364
Two-tailed probability of equaling or exceeding Z = 4.60227E-3

NOTE:  395 total observations.
```

```
                    Comparison of Two Samples
----------------------------------------------------------------
Sample 1: STD10.var23

Sample 2: HEWAT.var23

Test: Unpaired

Average rank of first group = 197.157 based on 340 values.
Average rank of second group = 203.209 based on 55 values.
Large sample test statistic Z = 0.457755
Two-tailed probability of equaling or exceeding Z = 0.647125

NOTE:  395 total observations.
```

Comparison of Two Samples

Sample 1: STD10.var24

Sample 2: HEWAT.var24

Test: Unpaired

Average rank of first group = 199.091 based on 340 values.
Average rank of second group = 191.255 based on 55 values.
Large sample test statistic Z = -0.559803
Two-tailed probability of equaling or exceeding Z = 0.575611

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var25

Sample 2: HEWAT.var25

Test: Unpaired

Average rank of first group = 190.75 based on 340 values.
Average rank of second group = 242.818 based on 55 values.
Large sample test statistic Z = 3.38161
Two-tailed probability of equaling or exceeding Z = 7.20723E-4

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var26

Sample 2: HEWAT.var26

Test: Unpaired

Average rank of first group = 194.671 based on 340 values.
Average rank of second group = 218.582 based on 55 values.
Large sample test statistic Z = 1.51718
Two-tailed probability of equaling or exceeding Z = 0.12922

NOTE: 395 total observations.

Comparison of Two Samples

Sample 1: STD10.var27

Sample 2: HEWAT.var27

Test: Unpaired

Average rank of first group = 192.599 based on 340 values.
Average rank of second group = 231.391 based on 55 values.
Large sample test statistic Z = 2.46724
Two-tailed probability of equaling or exceeding Z = 0.0136157

NOTE: 395 total observations.