Development of Indicators for the Measurement of the South African Publics' Relationship with Science

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DECLARATION

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Abstract

Post-apartheid South Africa has a number of social and economic challenges to overcome toward achieving a truly free and equal society. The South African government, in its *Ten-Year Innovation Plan* (2008) and *National Development Plan 2030* (2012) has committed to pursuing the goal of eliminating poverty and reducing inequality, through identifying science and technology as having a key role to play in overcoming the most pressing developmental areas in contemporary South Africa.

Critical to harnessing the power of science and technology is the promotion of a citizenry, skilled and scientifically literate, toward driving economic growth, development and sustainability. In order to achieve this, it remains important to identify the current levels of the South African *public understanding of science* (PUS). Previous research in South Africa has adopted international measurement techniques and yielded valuable insight. To date however, no indicators have been developed specifically within the South African context toward enhancing our understanding of the South African public-science relationship.

This study set out to develop a set of measurement indicators and adopted the following six elements to constitute the South African public understanding of science: *knowledge* of science; *attitudes* to science; *interest* and *informedness* about science; science *information sources*; and attendance at *science engagement activities*. The main objectives of the study were: 1) to determine the level of South African public understanding of science within each element; 2) to understand the patterns of PUS in relation to background demographic variables; 3) to develop indicators for each of the PUS elements and 4) to determine the key predictors of performance on each of the new indicators developed.

The empirical component of the study consisted of a national survey, in both urban and rural settings, yielding a total sample of 3 486 respondents.

Results from the survey indicate that South Africans correctly identified about 40% of the items on a *scientific knowledge* index. Considerable variation was revealed within this result by science subject area. Items dealing with *medical science* recorded correct response from 67.4% of respondents, while items covering the area of *astronomy* were answered correctly by 28.4% of the sample. Overall, 33.3% of respondents provided a scientifically incorrect response while 26.4% selected a *don't know* response.

Attitudes to science were assessed using three interrelated methods. South Africans displayed *moderately positive* attitudes to science, with an average of 70.3% of respondents agreeing with *positively worded* attitudinal items, while 58.2% offered agreement with the more *critical* attitudinal

statements. This result was further confirmed within the *Index of Scientific Promise and Reservation*, wherein South Africans achieved an index ratio of 1.21. An additional investigation was undertaken to determine *attitudinal ambivalence* within the response to this question set. Survey outputs indicate that 39.7% of our sample reports a *degree of attitudinal ambivalence.* This is of concern as it may lead to increased malleability of attitudes to science.

Among the 3 486 respondents, 22.6% indicated *high interest* in science while 33.0% indicated a *moderate* level of interest across the 7 areas of science included (55.6%). However, 44.4% indicated no interest in any of the areas of science listed. Respondents reported being most interested in areas of *Technology & the Internet*; followed by *Climate Change; Economics* and *Energy.* Within the same science subject areas, respondents indicated a generally lower level of *informedness*. An average of 45.3% of respondents reported being informed about the 7 areas of science. Overall however, 54.7% of respondents indicated that they were *not well-informed* with regards to the 7 areas of science items. South Africans report being best informed in areas of *Technology & the Internet*; followed by *Politics and Economics*.

This survey included 11 information sources to assess the most frequently used *source of scientific information*. South Africans predominantly report *Radio* (69.4%) as the primary source of scientific information. This was generally followed by *free-to-air television* (65.0%) and then *other people* (60.0%). All online-based information sources (social media; *blogs*; *institutional websites* and *news websites*) were ranked lowest across the 11 questionnaire items.

Respondents report a very low attendance at *science engagement activities*. Only 11.5% of respondents report attendance at one of the five listed science engagement activities. Among those that did attend an engagement activity the majority visited a *Public Library* (34.5%); followed by a *Zoo or Aquarium* (22.8%); *Museum* (18.3%); *Science Centre, Technology exhibition* (12.5%) and *Science Café, Festival or similar Public Event* (11.9%). A key finding from within this study is, despite the higher reported level of *interest* and *informedness* in areas of science, the majority of South Africans surveyed generally do not attend science engagement activities.

Through the use of *multinomial logistic regression* techniques, models were developed that explains respondent outcomes on each index.

Based on the results of this study, a more structured approach to public understanding of science measurement, with specific design considerations to the South African context now exists. The results of this baseline, nationally representative study further adds to the sources of data and scholarship within this domain. The findings responded to a number of hypotheses presented, which may provide direction for further research. The value of this research to policymakers, government, civic society and researchers is multi-fold. Firstly the development of rigorous indicators presents the opportunity for future iterations of this tool and monitoring of PUS trend data, toward evidence based decision making. The development of an audience segmentation model may further aid the development of targeted science communications strategies. The immediate benefit however rests in the rich data resource created that will aid future researchers within this domain.

Opsomming

Post-apartheid Suid-Africa het verskeie sosiale en ekonomiese uitdagings wat aangespreek moet word voordat die samelewing werklik vry en gelyk kan wees. Die Suid-Afrikaanse regering het, deur middel van die *Tien-Jaar Innovasieplan* (2008) en die *Nasionale Ontwikkelingsplan 2030* (2012), hom verbind tot die bestryding van armoede en ongelykheid, deur te beklemtoon dat wetenskap en tegnologie 'n sleutelrol speel in die dringendste ontwikkelingsareas in kontemporêre Suid-Afrika.

Dit is uiters belangrik om wetenskapsgeletterdheid en –vaardigheid in die samelewing te ondersteun ten einde die potensiaal van wetenskap en tegnologie tot die bevordering van ekonomiese groei, ontwikkeling en volhoubaarheid te benut. Ten einde dit te bereik, is dit nodig om die huidige vlak van Suid-Afrikaners se kennis en begrip van die wetenskap te identifiseer. Vorige navorsing in Suid-Afrika wat gebruik gemaak het van internasionale metodes het tot waardevolle insigte gelei. Tot op hede was daar egter nog geen indikatore ontwikkel – wat fokus op die Suid-Afrikaanse konteks – wat ons kennis van die Suid-Afrikaanse publiek se verhouding met die wetenskap kon verryk nie.

Die doel van hierdie studie was dus om 'n stel indikatore te ontwikkel vir die Suid-Afrikaanse kennis en begrip van die wetenskap wat die volgende ses elemente inkorporeer: *kennis* van die wetenskap, *houdings* jeens die wetenskap, *belangstelling* in die wetenskap, *ingeligtheid* oor die wetenskap, *bronne van wetenskaplike inligting*, en *wetenskaplike betrokkenheid ('engagement')*. Die hoof doelwitte van die studie was: 1) om vas te stel wat die vlak van Suid-Afrikaners se begrip en kennis van die wetenskap is met betrekking tot elkeen van die elemente, 2) om die patrone van die kennis en begrip van die wetenskap te verklaar met inagneming van die belangrikste demografiese veranderlikes, 3) om indikatore te ontwikkel vir elkeen van die element van begrip en kennis van die wetenskap, en 4) om vas te stel wat die faktore is wat meespeel in elkeen van die nuwe indikatore.

Die empiriese komponent van die studie behels 'n nasionale opname, in beide stedelike en landelike gebiede, wat 3 486 respondente opgelewer het.

Die opname het bevind dat Suid-Afrikaners ongeveer 40% van die items op die *kennis van die wetenskap indeks* korrek kon identifiseer. Aansienlike variasie was teenwoordig in die resultate per wetenskapsvakgebied. Vrae rondom die *mediese wetenskappe* behels is korrek beantwoord deur 67.4% van die respondente, terwyl items wat die vakgebied *astronomie* dek deur slegs 28.4% van die steekproef korrek beantwoord is. Oor die algemeen het 33.3% van die respondente verkeerde antwoorde verskaf, terwyl 26.4% aangedui het dat hulle nie weet wat die korrekte antwoord was nie.

Houdings jeens die wetenskap is geklassifiseer in drie kategorieë: Suid-Afrikaners toon 'n *matige positiewe* houding teenoor die wetenskap, met 70.3% van respondente wat saamgestem met positief-bewoorde *ehoudings* stellings, terwyl 58.2% met meer *krities-bewoorde houdings*stellings saamgestem het. Hierdie bevinding is herhaal in die *Indeks van Optimisme en Versigtigheid ('reservation') teenoor die Wetenskap*, waar Suid-Afrikaners. Verdere analise is onderneem om diegene wat 'n ambivalente houding jeens die wetenskap het. Die opname wys dat 39.7% van die steekproef ambivalent is in hul houding teenoor die wetenskap. Die bevinding is veral belangrik omdat dit 'n aanduiding kan wees wat houdings wat meer veranderlike is.

Van die 3 486 respondente het 22.6% 'n hoë vlak van belangstelling jeens die wetenskap, terwyl 33.0% 'n matige belangstelling in wetenskapsaangeleenthede het 'n Beduidende proporsie (44.4%) het aangedui dat hulle geen belangstelling toon in enige van die wetenskapsvakgebiede nie. Respondente blyk die grootste belangstelling te hé in die volgende onderwerpe: *Tegnologie endie Internet*, gevolg deur *Klimaatsverandering*, *Ekonomie* en *Energie*.

Hierdie opname het 11 opname items ingesluit om te bepaal watter bronne Suid-Afrikaners oor die wetenskap gebruik. Suid-Afrikaners het *Radio* (69.4%) as hulle primêre bron van inligting oor die wetenskap aangedui. Dit is gevolg deur *gratis direkte televisie* (65.0%), en dan inligting verkry deur *ander mense* (60.0%). Alle vorme van aanlynbronne van inligting (*sosiale media*, *webjoernale*, *institusionele webwerwe*, en *nuuswebwerwe*) het die laagste posisie beklee van al 11 van die opname items.

Volgens die opname blyk dit dat Suid-Afrikaners nie baie by wetenskaplike aangeleenthede betrokke is nie Slegs 11.5% van die respondente het aangedui dat hulle aan enige van die vyf vorme van wetenskaplike betrokkenheid Deelgeneem het Van diegene wat wel van die responsopsies gemerk het, , was *Openbare biblioteke* (34.5%) die meeste besoek, gevolg deur 'n *Dieretuin of Akwarium* (22.8%); *Museum* (18.3%), *Wetenskapsentrum, Tegnologie uitstalling* (34.5%), en *Wetenskapskafee, fees of soortgelyke Openbare geleentheid* (11.9%). 'n Belangrike bevinding van die studie is dat ten spyte van die hoë vlakke van *belangstelling* en *ingeligtheid* wat vermeld was in sekere van die wetenskapsvakgebiede, dui hierdie studie aan dat die meerderheid van Suid-Afrikaners nie baie betrokke is by wetenskapaktiwiteite nie.

'n Meer gestruktureerde benadering tot Suid-Afrikaners se kennis en begrip van die wetenskap is 'n hoofuitkoms van hierdie studie. Die bevindinge van hierdie nasionaal verteenwoordige studie maak 'n belangrike bydrae to die databronne en navorsing op hierdie terrein. Die bevindinge spreek 'n aantal hipoteses direk aan, wat toekomstige navorsing kan inlig. Die waarde van hierdie navorsing vir beleidmakers, die regering, die burgerlike samelewing en navorsers is veelvoudig. Eerstens, bied die ontwikkeling van geldige en begtroubare indikatore die geleentheid vir toekomstige replikasies van hierdie studie sowel as vir die gereelde monitering van die Suid-Afrikaanse publiek se kennis en begrip van die wetenskap. Die ontwikkeling van 'n segmentasie-klassifikasie van die Suid-Afrikaanse publiek op grond van hule response is ook waarevold om toekomstige wetenskaps kommunikasie strategieë te ontwikkel.

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Dedication:

To my grandparents, Hajji's Mohamed Ameen & Habiba Parker as well as Ayesha Ebrahim Datay, you are the giants, whose shoulders we stand on.

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AIDS	Acquired Immune Deficiency Syndrome
AMCOST	African Ministerial Council on Science and Technology
ASTII	African Science, Technology and Innovation Indicators Initiative
Attitude	A settled way of thinking or feeling about someone or something, typically one that is reflected in a person's behaviour.
AU	African Union
B.S.E	Bovine Spongiform Encephalopathy
CAPI	Computer-Aided Personal Interviews
CAST	Chinese Association for Science and Technology
CATI	Computer-Assisted Telephone Interviewing
CoPUS	Committee on the Public Understanding of Science (Britain)
CPA	Consolidated Plan of Action (AMCOST plan)
DDT	Dichlorodiphenyltrichloroethane - pesticides banned in 1980's
DST	Department of Science and Technology (South Africa)
Engagement Activities	A highly inclusive approach (to science related activities). Allows people to join the public dialogue surrounding science and provides them the tools to do so productively
GDP	Gross Domestic Product
GERD	General Expenditure on Research and Development
GMO	Genetically Modified Organisms (usually crops, but also animals)
HE	Higher Education
HSRC	Human Sciences Research Council – South Africa
ICT's	Information and Communication Technologies
Informedness	The state or quality of being *informed*
Interest	Something that concerns, involves, draws the attention of, or arouses the curiosity of a person
KE	Knowledge Economy
Knowledge	Facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject
Knowledge Economy	A knowledge driven economy is one which recognizes the important contribution and benefit information and technology can bring toward national productivity, and actively seeks to develop systems of deriving real progress from these benefits
Matric	In South Africa, matriculation (or matric) is a term commonly used to refer to the final year of high school and the qualification received on graduating
MGD's	Millennium Development Goals
NCAER	National Council of Applied Economic Research (India)
NEPAD	New Partnership for African Development
New Technologies	Often digital, Some examples may be the Internet, websites, computer multimedia, computer games, CD-ROMS, and DVDs
NSF	National Science Foundation (United States of America)
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development
Old Technologies	Including: broadcast and television, radio, movie and music, newspapers, magazines, books and most print publications.
ONS	Office of National Statistics - UK

PPP$	Purchasing power parity is a theory in economics that approximates the total adjustment that must be made on the currency exchange rate between countries that allows the exchange to be equal to the purchasing power of each country's currency.
Public	All citizens of the research setting (South Africa) - unless specific publics are referred to
PUS	Public understanding of Science
R&D	Research and Development
RDD	Random digit dialling - fieldwork method using telephone surveying techniques
S&T	Science and Technology
SASAS	South African Social Attitudes Survey
Science	A systematically organized body of knowledge on a particular subject
SEI	Science and Engineering Indicators (Biennial indicator publication of the NSF)
STI	Science, Technology and Innovation
Understanding	How information is processed and used - in this research it has specific reference to science
Web 2.0	relates to the emergence of more interactive and collaborative web-based interactions, rather than the earlier static web pages of the early online experience

Chapter One

GENERAL INTRODUCTION

"Science creates conditions for economic and national development, which in the near future will support the process of social and economic transformation of the country. To reach this goal, it will be essential to link science effectively with other areas of social and economic activity, and with education in particular."

White Paper on Science and Technology
Department of Science and Technology, South Africa (1996)

1.1 THE HISTORY AND CONTEXT OF SCIENCE & TECHNOLOGY IN SOUTH AFRICA

The history of science in Africa dates further than initially believed by Western archaeology, with impressive civilisations, like the Kingdom of Nubia (400 AD) and Great Zimbabwe (1 100 AD), producing startling evidence of tremendous technological know-how long before the arrival of European explorers. These technological skills, highly advanced for the time, spanned all fields from learning systems, astronomy, mathematics, metallurgy, medicine, agriculture, textile, maritime engineering, architecture, communication, warfare and commerce (Pwiti; 1991). This rich history of cultural and technological achievement has been somewhat lost in the colonial writing of African history, but in recent times has been rediscovered and brought to the fore in the academic and popular literature. South Africa is no stranger to this rich, lost, history, with Mapungubwe (1 000 AD) having been situated just 65 km north of Polokwane, present day Limpopo Province. This early African kingdom shared much with the (later) Great Zimbabwe, including the facilitation of continental African trade with the Far-East, serving as an ivory and gold exchange and trading post, using well established currency and being a centre of much technological advancement (Hrbek *et al,* 1988, Pwiti, 1991; Tiley-Nel, 2010). The advanced capabilities with respect to science and (particularly) technology of early African societies represented a critical investment in the social development and expansion of influence across the neighbouring regions. African technological achievements have spanned the long history of civilisation on the continent and despite the lack of visibility in modern science, still continue to contribute to scientific endeavours (Tiley-Nel, 2010).

In the recorded history of formal Western science in South Africa, the colonial era brought with it many of the modern scientific disciplines we recognise today. Mouton *et al* (2001) present a brief history of science in South Africa identifying five key periods in South African science that saw the development and formalisation of many of the elements we see today in the South African National System of Innovation. These five periods include the *Colonial era* (1751 – 1880) *Industrial era* (1880 – 1910) *War Time Science in South Africa* (1910 – 1948) *Apartheid Era Science* (1948 – 1994) and the *Post-Apartheid scientific system* (1994 – present). Each of these periods is bookmarked with key developments and societal dynamics that changed the context and direction of the scientific enterprise moving ahead.

During the colonial era many early travellers to the Cape Colony participated in endeavours of amateur scientific research. European scientific communities saw the new territory at the Southern tip of Africa with keen scientific interest. Astronomy, botany, zoology, military science, geology and engineering all benefitted the European settlers politically, commercially and in terms of developing basic local infrastructure to support the Colony. Moreover these early scientists in the Cape also contributed to the general stock of scientific knowledge within and across the various fields mentioned above – much of which appeared in early European scientific journals as the collected data travelled back to Europe with the increasing popularity of the shipping routes around the *Cape of Good Hope*. By the early 1800s a growing scientific community in the Cape, often venturing inland across central South Africa, began establishing many domestic scientific outposts, formalising their work and soon the Cape Colony saw the establishment of some of the first scientific institutions in South Africa. The first of these was the Royal Observatory in 1820, The Royal Society in the early 1820s and the South African Museum in 1825 (Mouton & Geevers, 2009). Many of these institutions are still active today and continue to contribute significantly within their respective disciplines. However within the early days, many of these institutions served in minimal ways as knowledge producing centres and instead more as staging points for visiting academics and resident researchers. Many of these early facilities occupied the role as a repository for the numerous botanical and zoological samples collected by various scholars. This model of colonial science is reflected in much of Africa, as the march of colonialism through Africa is deeply connected with science and exploration on the continent. Many of these early scientific institutions had from the beginning seen a certain degree of political sway, as much of South African history, even scientific and educational history is infused with clear notes of political influence and ideology, a point that will be revisited later in this chapter. The establishment of botanical gardens in numerous African countries, much like the Kirstenbosch Botanical gardens in Cape Town (1913) is a hallmark of the colonial scientific influence, many of which continue as attractions and botanical centres in African cities today (Mouton & Boshoff, 2010).

With the discovery of mineral wealth, South Africa saw the rapid industrialisation of science (Worden, 1994). The link between industrialisation, science, technology and development continued in 1876 as the first telegraphic communications lines between Cape Town and Kimberly were established, supporting the diamond mining boom of the 1860s (Perkins *et al*, 2005). Gold and diamonds catapulted the arrival of many mining, geological, geographical, chemical and engineering scientific personnel to drive these required fields of science within the growing South African economy. Employment in the sciences was finally a reality in South Africa (Mouton *et al*, 2001).

As in many other countries the reality of life is often reflected in the type of scientific endeavours invested in. However beyond the economic and engineering opportunities encountered, the rapid industrialisation lead to increased concentration of human settlement, bringing with it the real social and health issues that overcrowding and poor planning often do. This lead to the establishment of the Onderstepoort Veterinary Institute in 1908 (MRC, 2001; ARC, 2011), and the South African Institute for Medical Research in 1912 (Murrey, 1963; MRC, 2001) responding to the growing needs of many of the fledgling cities that sprouted up in reaction to the mineral wealth that was making its way to the surface across South Africa. The economy, still highly dependent on domestic agricultural success, saw the growing need for agricultural research, with threats such as the tsetse fly, rinderpest and bilharzia not only decimating cattle stocks but also proving to be serious threats to human inhabitants of South Africa (MRC, 2011). It has furthermore been argued that one of the foremost reasons for the establishment of the *South African Institute for Medical Research* (SAIMR, later the MRC) was due to the high incidence of serious illnesses among African mine workers (MRC, 2001), this alludes to motivational reasons for the establishment of these institutions serving a greater economic need, than the more obvious social health imperative of the time, again alluding to the political and ideological infusion of the scientific history in South Africa.

Following the formation of the Union of South Africa (1910-1961) and the outbreak of *World War* 1 (1914-1918), South Africa along with its citizens and scientists were flung into the conflict supporting allied troops, under Louis Botha, as a result of the historical ties with the British Empire in the Cape (Byrnes, 1996). The involvement in the war led directly the first South African *Science and Technology Planning Frame*work in 1916 (Scerri, 2008) spurred on by the increasing levels of technological application and mechanisation at the front lines, and more importantly the (initial) technological dominance of the German forces against the Allies (Kennedy; 1989). This framework served the purpose of unifying all policy directing activities for trade, industry, education as well as science and technology and was formulated by the *Scientific and Technical committee* of the *Industrial Advisory Board* within the *South African Ministry of Mines and Industry*. This government led approach, influenced by the war-time effort, and was later abandoned in favour of a more non-interventionist approach allowing greater private initiatives and influence in science and technological issues. By the 1920s however, President Jan Smuts appointed HJ Van der Bijl as the

Scientific and Technical advisor to the South African government. In his career Van der Bijl had one of the most remarkable impacts on the science and technological landscape of contemporary and future South Africa, plotting the way toward continued state involvement in selected sectors of the economy. Van der Bijl is recorded as being the leading figure in motivating for the development of many parastatal's (state owned enterprises) and science councils still in operation today (Scerri, 2008; Mouton & Geevers, 2009). These include the *Electricity Supply Commission* (ESKOM), *The Iron and Steel Corporation* (ISCOR), the *Industrial Development Corporation* (IDC) and one of the contemporary science councils – the *Council for Scientific and Industrial Research* (CSIR).

The early 1930's saw the development of the first well-funded social science research project in South Africa. Funded from the United States of America, under the Carnegie Institute, the study investigated the causes, effects and possible steps toward curbing the growing issue of *white poverty* in South Africa (Fourie 2006). The eruption of the Second World War began a new era in South African science, with many new institutions and resources diverted toward ensuring sustainability within the country during this time (Mouton & Geevers, 2009). With the realisation that a more coherent assimilation of technology and development was required in South Africa, the CSIR was tasked with an increasing number of research problems and today is still one of the major research and development (R&D) performers in the country, accounting for nearly R 2.3 Billion in R&D expenditure annually (HSRC, 2010). The period around World War 2 was a very fertile period for South African science, seeing the beginnings of many of the science councils that still perform vital roles in modern South Africa.

With the dawn of apartheid in 1948, the eventual isolation of South Africa under sanctions saw the next era for science (1948-1994) as there had been a shift in national strategic focus, toward a more defence dominated science industry. During this time, despite the global isolation in South Africa, domestic scientists managed to produce promising research, particularly in the energy and nuclear sectors. South Africa in this time successfully developed six nuclear weapons (Pike, 2011, Albright, 1994), and began successfully implementing mass industrial technology for coal-to-fuel synthesis (Sasol, 2005). Many of these developments were successful due to not only a strong drive from Government, but in many ways also due to the influence of a, by then, well-developed Higher Education and Science Council sector. This was a period of dramatic growth for the South African science system, with increasing publications and citation counts far exceeding growth of international counterparts. However despite this growth, due to the influence of apartheid, many of the brightest South Africans opted to leave a country under segregation and contributed significantly to the brain drain experienced in the late 1980's (Crush *et al, 2005,* Ndulu, 2004, Bhorat *et al*, 2002). The brain drain together with limited access to the international scientific community further impacted South Africa's science and technology development, though progress still ensued during this time. This all against the background of unequal access to Higher Education, based on racial grounds, alienated the majority of the population from the world of science and contributed significantly to South Africa's immediate and future science and technology (S&T) outlook. Christopher King notes, "*South Africa's scientific profile appeared to reflect the high cost of isolation from the world community, as evinced by a low representation of published papers and low citation impact compared to the rest of the world"* (King, 2010).

A short discussion around apartheid era educational policies is important at this stage. Education under apartheid, as with many other aspects of life for the majority of South Africans was severely impacted by the policies of the National Party Government. Laugksch (1996) cites the research of Hartshorne (1992), Molento (1984) and Kallaway (1984, 1991) in developing a picture of education under the various apartheid laws. Prior to 1948 there had been no coherent educational policy active in South Africa (Laugksch, 1996). However in 1948, the focus of the apartheid government relating to black education put in motion a number of transformations that would set the tone of African education over the next 50 years, and till today impacts the populations of South Africa through the legacy impacts of separate educational standards for black, coloured, Indian and white communities. During this period there was a deliberate policy toward limiting the educational attainment standards of non-white citizens. This policy sought to ensure that these members of the population were purposefully literate in limited areas of expertise, so as to adequately equip them for menial positions in satisfying the demand for cheap labour in white-controlled industries. Certainly Africans were most notably disenfranchised through these policies, however in lesser degrees; coloured and Indians too were adversely impacted by these limited educational resources, opportunities and general levels of educational attainment. As a result of the various educational boards[1] that existed to oversee educational standards for the various race groups in South Africa, the educational outcomes at the pre-school-leaving year (grade 11) were varied to meet the set standards of the apartheid era policies. However further impacting this was the national policy that all black school leaving candidates (matriculants) wrote a national exam set by the National Department of Education and Training (DET, previously the department of Bantu Education). Furthermore for white, coloured and Indian candidates these school-leaving examinations were set

[1] At one stage there were 18 different educational boards, racially divided within the, then, 4 South African provinces (Laugksch, 1996)

by the various provincial departments of education overseeing the education of these groups. All matriculation certification was awarded through a process of moderation by the, then, Joint Matriculation Board, applying a similar standard to all candidates. These policies failed to take into account the varying standards of educational outcomes of the numerous provincial and racially delineated educational departments. This impacted significantly on the number of non-white matriculants successfully completing the grade 12 examinations with a school-leaving certificate or matriculation exemption, required for university enrolment. This directly influenced the number of non-white learners able to enter tertiary education, and thus influenced, and continues to demonstrate social influence on the national university entrance and graduate outputs at all major South African universities. The historical and contemporary impact of these policies directly influences the human resource capital of contemporary and future South African science and technology progress, as will be further addressed later in this chapter.

With the increasing liberalisation of the early 1990s, the new democratic government (post-1994) began driving science and educational policy initiatives, not only to encourage the return of many South African scientists, now stationed abroad, but also to foster a new generation of young scientist from across racial classifications, to drive the development of a more inclusive national scientific system. The new *Department of Arts, Culture, Science and Technology*[2] developed numerous key policy documents to further this goal through various investment, educational, and social projects in order to build a national system of innovation (NSI). Despite the massive efforts on the side of Government, and the numerous stakeholders within the NSI, there is still a long way to go as many gaps still exist toward building an effective and sustainable national science system. Ellis (2001) notes that South Africa in the 21st Century will be part of a global science system...*However it will be unlikely that South Africa may become a great power in the global knowledge economy*. This is in particular reference to the marked shortage of a suitably qualified human resource capital within the country to drive the growth of a knowledge economy. If this skills gap is to be effectively filled, South Africa must ensure that a future workforce is given a strong foundation in science and technology (S&T) education, from the primary school level in order to develop an appreciation for S&T as they enter the workforce (Ellis, 2001). The Organisation for Economic Co-operation and Development (OECD), in its report on *South African Innovation Policy* recognises the considerable efforts government has made toward improving education policy and resources in attempting to address the issues of human capital shortages (OECD, 2007). However further support for post-graduate students, greater incentives toward completion of a PhD, reassessment of the university funding

[2]Later to split into Department of Arts and the Department of Science and Technology

systems to increase access to tertiary education, together with greater incentives to the private sector to encourage knowledge investments, and greater focus on international competitiveness have all been suggested toward bolstering a scientifically aware workforce in South Africa (Kaplan, 2008b)

South Africa has started developing key capabilities in measuring and understanding the National System of Innovation. In post-apartheid South Africa, institutions like the National Advisory Council on Innovation (NACI), Centre for Research on Science and Technology (CREST), the Centre for Science Technology and Innovation Indicators (CeSTII) and many others all play key roles in measuring and developing indicators for the performance of the national system of innovation.

1.2 <u>THE MULTI-FACETED NATURE OF THE SOUTH AFRICAN PUBLIC</u>

Perhaps the greatest paradox of human development today is that for there to be prosperity, there almost always must be poverty (Yechury, 2008). Nowhere is this more true than in Sub-Saharan Africa, with more than 45% of the populations being classified as *poor* or *extremely poor* (Chen & Ravaillon, 2004). In South Africa, a country of 51.7 million people (Census, 2011), there exists a stark contrast in the levels of inequalities among its citizens, having a definite current and future impact on ordinary citizens. South Africa is home to an increasingly diverse population, apparent not only in the many cultures, traditions, languages and religions, but also with regards to particular social aspects relating to access to education, income distribution, basic services and employment (see Table 1.1). Many of these can be traced back to the legacy impact of apartheid; however since 1994 there has been a dramatic rise in the number of wealthy black individuals, and an economically powerful non-white middle class (van der Berg & Louw, 2003). Yet despite these changes, the vast majority of South Africans are still in a state of poverty, closely interrelated with income and other forms of inequalities that seem to perpetuate this cycle of social stagnation.

When exploring the *public* understanding of science in South Africa, these rampant and broad-based inequalities have led to a highly stratified society (van der Berg, 2010). Reddy *et* al (2009) propose that it may be analytically useful to refer to the many strata of the South African populous as the *public**S***, accounting for the vast disparities that exist and reflecting the heterogeneity within the population. When looking at selected demographic indicators, even at the highest level, these inequalities shine through, despite limited real improvements and policy intervention during the 22 years of democracy. Since 1994 the South African population has grown by some 12.3 Million individuals, which is an average increase of 9.52% every 5 years. This population change has further been impacted by the outward and inward movement of individuals in South Africa through immigration and emigration since 1994 (Polzer, 2010; CIA, 2012).

Historically (as discussed above) access to equal education, across the racial groups was severely impacted by the pre-1990 apartheid policies. Since 1994 government have made concerted efforts to correct the imbalances of these policies and consistently invested the larger share of the national budget toward education in South Africa (Khumalo, 2013). The results of the 2011 National Census indicate that a considerably higher number of non-white learners now have access to free basic education, as well as onward higher and tertiary education than during the pre-1994 era, with an average of 73.5% of South Africans between the ages of 5 and 24 years old now attending some form of educational institution (StatsSA, 2012).

	African	Coloured	Indian	White	RSA
Population	79.63%	8.96%	2.50%	8.91%	100.00%
Education*	73.9	67.2	71.8	77.7	73.5
Average Annual Income	R 60 613	R 112 172	R 251 541	R 365 134	R 103 204
Access to running water**	32.45%	82.79%	97.02%	94.10%	43.27%
Access to Electricity***	66.90%	89.44%	94.85%	95.05%	72.59%
Access to Flush Toilet****	46.85%	86.88%	97.29%	92.49%	56.49%
Unemployment*+	28.80%	23.30%	12.30%	7.20%	25.20%

* % Persons attending an educational institution amongst those aged 5–24 years by population group (PO3014 Census 2011)

** % With piped (Tap) water in dwelling (PO318 GHS 2011)

*** Electricity from mains (PO318 GHS 2011)

**** Flush toilet connected to a public sewerage system (PO318 GHS 2011)

*+ Quarterly Labour Force Survey Quarter 1, 2013 (PO211)

Table 1.1: Selected South African demographic and population indicators (Stats SA 2011)

Despite this, according to the results of the 2011 National Census, only 28.9% of the total population completed Grade 12 schooling (see Chart 1.1, StatsSA 2012). Furthermore of these matriculants, 8.3% of Africans, 7.4% of Coloured, 21.6% of Indians and 36.5% of White learners continued on to enrol for a tertiary qualification.

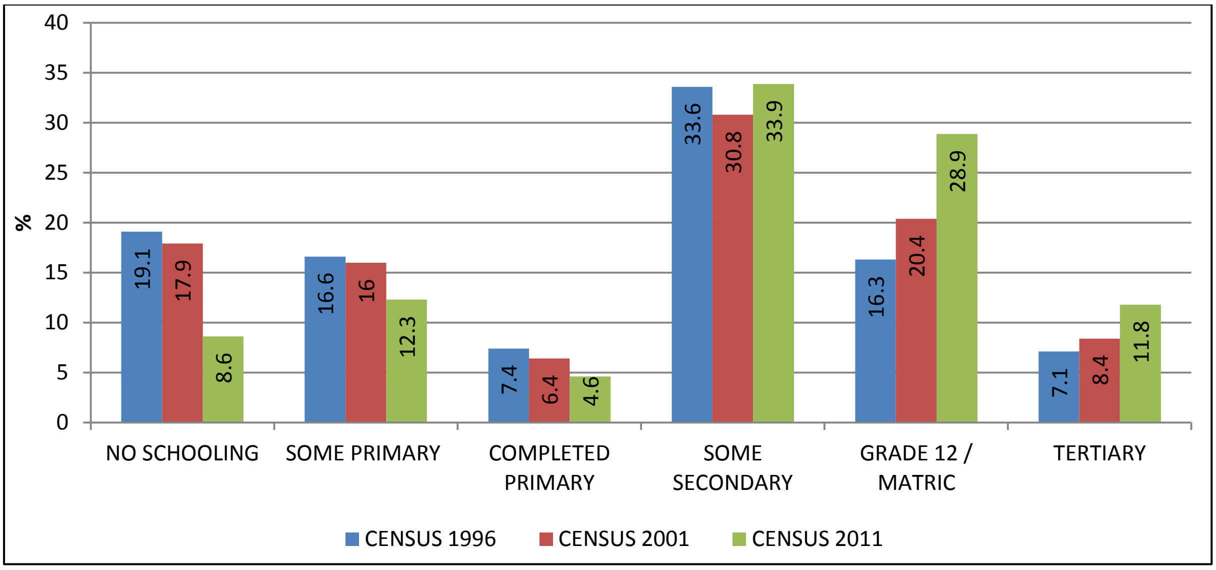

Chart 1.1: Highest Level of Education Attained, South Africans 20+ years old (Stats SA 2011)

While economic realities and related social factors do impact on access to further education, the dismal state of education in South Africa has increasingly come under the spotlight within the recent past (see Kumalo, 2013; Weeks, 2013) and further contributes to the poor matriculation results and thus access to continued educational opportunities.

Despite the 22 years since the end of apartheid and the general refrain from race-based social systems (population group) in South African society, the legacy impacts of apartheid across racial stratifications is still apparent and thus made reference to within this section to provide some understanding of the multifaceted nature of South African society. As with access to education, data on income distribution (and other demographic factors) reveal these in startling contrast. In Table 1.1 (above) the average income is presented by population group, and clearly displays the inequalities that exist with respect to income distribution in South Africa (StatsSA, 2011). On average Black South Africans earn between 16% and 20% of the average annual salary of a White South African, and while this is not due to blatant employment discrimination[3], it does have a definite impact on the standard of living and accessible opportunities for the majority of the South African population. Linked to this is the high unemployment rate of 26.7% in South Africa (StatsSA, 2016), with a higher concentration in the non-white population groups, linked to education, skills shortages and available opportunities for unskilled individuals. All of these population indicators are interrelated in terms of their social impacts, and is highly stratified by race when looking at the access to basic services in Table 1.1.

[3] The opposite is very clear through government transformation policies liked to *Broad Based Black Economic Empowerment,* however many have questioned its success and reach in light of the limited skills base in South Africa

Linked to the above it remains evident when looking at selected global economic and developmental indices that in some ways reflect the reality of the South African public. Key here is South Africa's high *GINI coefficient* of 63.1 (income inequality), which is the second highest in the world (CIA, 2012), as well as a rising *Human Development Index* rating of 0.629, ranked at 121st in the world (UNDP-HDI, 2013). However, that being said, for other indicators these realities are skewed as a result of these inequalities. A case in point is the figures for Gross Domestic Product (GDP). South Africa reported a total GDP of $390 Billion USD in 2012 (IMF, 2013) which placed it at a world ranking of 25 out of 196 countries for Nominal GDP figures worldwide, considerably higher than many developed countries for this period (CIA, 2012). However that being said much of this can be attributed to a small group of highly profitable industries and related high-income earners that sharply increases average incomes, thereby contributing to overall GDP figures, but simultaneously increasing the GINI coefficient and increasing the negative impact on other social indicators. This is evident when considering that 42.9% of South Africans live on less than R 420 per month (less than $2 US Dollars a day) while 26.2% live on less than R 260 per month which equates to less than $1.25 US Dollars per day (UNDP-HDI, 2008). While certain sectors of the non-white South African population have managed to attain incredible success post 1994, the vast majority of South Africans face the poverty discussed above. These inequalities are rooted in history and manifest in the reality many South Africans face today. The divides on income, access to services, education, employment and education have all widened an already broad chasm of social development within the South African public (Langa *et al*, 2006). Understanding this development divide is fundamentally important to effective planning and implementation of many of the bold strategies planned by government in both urban and rural centres. This paradox of present day South African society has a definite impact on the present and future of social and human resource development, fundamental to the continued growth of South Africa (Fedderke, 2001).

The 2016 Quarterly Labour Force Survey indicates that unemployment among the South African public is increasing and is currently at 26.7% (StatSA, 2016). Contributing to the cause, and as a result of this vast unemployment in South Africa, is the historic poor access to education, and current poor quality of education that dramatically impact on school-leavers abilities to find suitable employment (Prinsloo, 2008). In very many ways these cyclical *cause and effect* relationship between unemployment, education and access to services perpetuates the on-going social stratification and inequalities in South African society (Seekings, 2003). However due to the multi-faceted nature of the South African population these inequalities vary across the many segments of the South African publicS. Reddy *et al* (2009) note variation in levels of education among the general population of South Africans. Among these, stratifications exist not only for race, as discussed above, but also for gender and age. Interestingly, among the younger age groups, access to and completion of high school (grade 12) is greater than for many in the older age stratifications, as a result of legacy impacts discussed above, and the political and social changes in South Africa post-1994. This is a promising sign for future public engagement with science, despite its minimal effect on enrolment for tertiary education and eventual employment in knowledge industries in South Africa.

The Department of Science and Technology, in its *Ten Year Innovation Plan* (2008) highlights the importance of a S&T (Science and Technology) skilled population, leading toward a highly skilled future human resource base, in meeting the goals of establishing South Africa as a premier knowledge economy by 2018. According to the *National R&D Survey 2009/2010* (HSRC-CeSTII, 2012), the number of *researchers per 1000 of the labour workforce* is 1.5. This is in stark contrast to many developed countries like Australia (8.5), Norway (10.1), Sweden (10.5) and Japan (10.4) (OECD, 2010). The low number of skilled S&T-workers in the South African workforce has an impact not only on a planned knowledge economy development, but also the future success of the National System of Innovation. This secondary impact is due to the fact that people skilled in S&T areas are not only needed to respond to the many social and developmental issues in South Africa, but also to answer the call for experienced and effective teaching within higher and tertiary educational institutions (Kraak, 2008). The inequalities discussed above, together with the resulting poor access to quality education and onward tertiary opportunities place a dire bottleneck on the stock of future skilled-human resources in knowledge industries and teaching facilities. This negatively impacts the goals of the *DST Ten-Year Innovation Plan* as human capital development and knowledge generation are intimately connected to the effective training and deployment of future science and technology capability in any system of innovation (DST, 2008; DST, 2011).

Despite the availability of social services and funding toward continued education for top students across population categories, the impacts of the vastly stratified socio-economic realities have in many ways yielded a non-homogenous nature within the South African public(S). This, together with the aforementioned cyclical links between poverty and education makes understanding the nature of the many segments of the South African population more of an imperative today than ever before. As the economy shifts toward more knowledge intensive approaches across the various economic sectors, the increasing specialization of skills throughout the workforce will begin to exert an impact on the many unemployed and under-skilled members of the South African public, immersed in an environment requiring ever-greater scientific and technological proficiencies. This reality exists not only for the traditional unskilled labour classification that has existed in South Africa, but also into the skilled and highly skilled groupings. Technology permeates all areas of the economy, bringing with it the benefit of efficiencies in process and production for those able to engage them, yet also a challenge to those not intimately familiar with the technological changes within these environments. Therefore the human resources requirement of the future within both traditional high-tech and low-tech industries will have to adapt and evolve to meet the new requirements of an economy undergoing rapid change to remain in-sync with global systems of innovation and competitiveness. The argument as to whether, in a technologically advancing world, science and technology must be made more accessible, in line with the abilities of the general public, or if the education of the general public must be sufficiently augmented to deal with the demands of modern technology is an interesting one (see Lodge, 2012, Shamos, 1995). The view within this thesis is that while accessibility of S&T is of utmost importance, for the generation of new knowledge producers and the future success and competitiveness of a country, knowledge and understanding of science and technology is a far greater attribute to have within the general population for the myriad of reasons noted above and below. While there are counter arguments to the beneficial impact of increased scientific literacy, which will be addressed toward the end of this chapter, the general consensus among the academic, educational and research community is that knowledge and understanding, not only of science and technology, but in any field is an attribute that should be desirable in all societies. A society educated and knowledgeable in fundamental scientific understanding is best positioned to promote this culture of learning to subsequent generations and prepare the groundwork for continued successful science and technological endeavours toward building a stronger nation. In an age of global competitiveness, science and technology represents the most effective tool for developing nations and communities to leap ahead and bridge the digital and social divides. Science and technology further presents a viable economic benefit that these nations and communities can harness toward accessing greater educational and competitive advantages toward breaking the cycles of inequality that permeate all spheres of life within these societies.

1.3 S&T AS AN ENGINE OF INNOVATION, COMPETITIVENESS AND ECONOMIC DEVELOPMENT

Science and technology (S&T) have considerable potential for the enhancement of quality of life and the advancement of society, particularly in the developing world where it may have the greatest impact in accelerating the drive to close the social divides experienced by the public as a result of the many social inequalities discussed above (Tongia et. al., 2005). The benefits related to S&T have an impact at a number of levels including the regional, national, community and individual level of influence, ranging from issues of individual and national health care, social development, access to resources as well as economic empowerment, job creation and cross-regional trade. The relationship between S&T and *the public understanding of science* is multi-directional, with accessibility and education in S&T influencing the general public understanding of science and similarly the public understanding of science impacting on the access, use and education in areas related to science and technology. This cyclical relationship is seen as a major priority within the education and policy environment, where effective general and scientific education forms the foundations of future growth within a country.

The importance of science, technology and innovation (STI) in relation to economic growth has been studied since at least the 18th century, with Adam Smith noting not only the productivity gains, specialisation of labour and related economic benefits but also the technological improvements S&T offers the entire system of production (Torun-Cumhur Çiçekçi, 2007). In the United States of America, economists believe that innovation is responsible for between 50% and 80% of all economic growth (Centre for American Progress, 2012). These shifting modes of production and economic models have been noted across global economies, leading to rapid growth, particularly in many developing world countries. A key example of this would be the change in modes of production within industrialised countries, and more recently within developing world nations, where responsible mechanisation, process innovation, enhanced human resource training and quality control measures have reduced cost of production and thus accessibility of goods and services to consumers (Pouris, 1989, Laugksch, 1996, DST, 2007). This has led to increased job creation, economic activity and stimulating system-wide economic growth and competitiveness. While it is abundantly clear that greater efforts are still required, particularly in the developing world context, strong evidence exists to drive the growth of a nation through the harnessing of the tremendous power of science, technology and innovation (Goedhuys, 2007, Egbetokun *et al*, 2008). It must be noted that education alone is not the primary success factor in addressing national growth and development through S&T, but it remains part of a complex interaction of the various building blocks of any successful economy, including workforce development, industrial readiness, continuous infrastructural development, directed policy and good governance practices (American Progress, 2012). As with all advances STI has also been noted for certain “negative economic impacts”, including disruptive innovations, obsolescence, irresponsible mechanisation (potentially resulting in job losses) and some argue the unequal economic benefit that may be derived from enhanced production processes thereby perpetuating social inequalities within societies (Pianta, 2004, Anderson *et al*, 2009). These voices, however valuable, are noted and do not distract from the goal of fully utilising STI toward enhanced growth and social development.

The earlier discussion on *the multi-faceted nature of the South African public* highlighted a number of pressing social issues still impacting on contemporary South Africa as a legacy of the inequalities created under apartheid (section 1.2). Academics and government alike have recognised the enormous impact STI will have in addressing and reducing the many inequalities experienced by the vast majority of South Africans (DST, 2007). Key to achieving this ambitious goal lies in driving the development agenda and enhancing investment in the related areas of education, infrastructure development, science and technology (DST, 2011). South Africa is leading the charge on the African continent though the expansion and investment in building its strategic S&T capabilities.

Since 2001, South Africa has consistently invested in R&D activities across all sectors of the economy (see chart 1.2). Similarly S&T researcher headcounts has grown consistently across this period, evidence of the concerted efforts to drive S&T capabilities within South Africa. While investment in research activities and the development of researchers have shown improvement across the period, these numbers remain relatively small in relation to the total size of the population and the relationship of *research spend to GDP* in South Africa (HSRC-CeSTII, 2012).

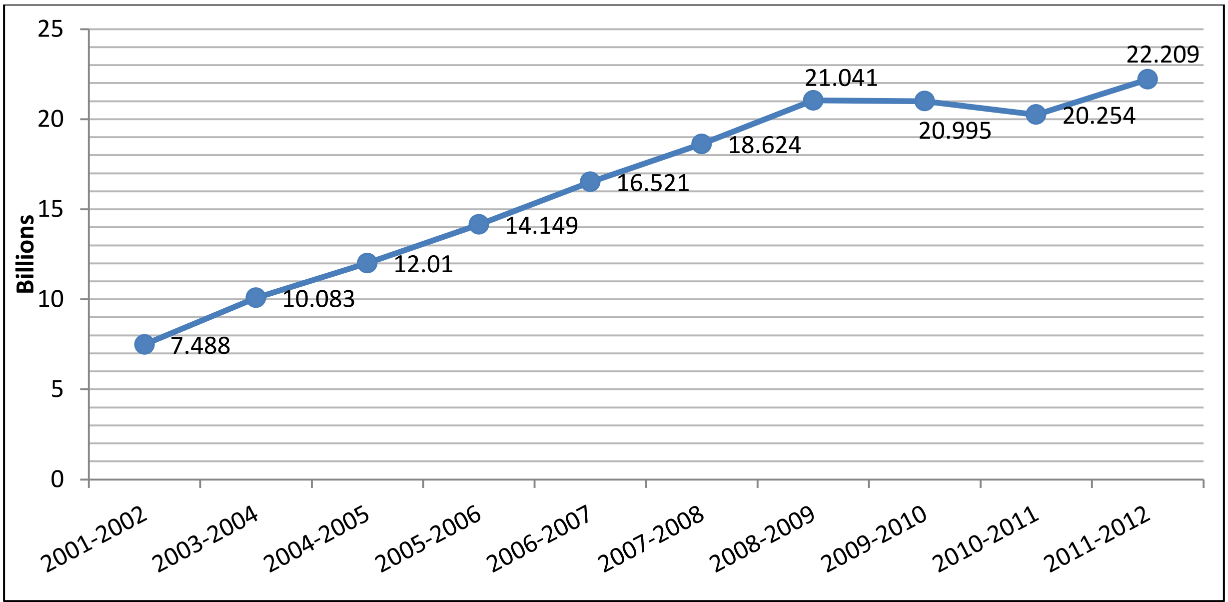

Chart 1.2: South African nominal R&D Expenditure 2001-2012 (HSRC, 2012)

Though South Africa has the most developed science and technology system on the continent, in recent years other countries further North in Africa have developed investment in S&T, including Egypt, Tunisia, Malawi and Uganda, among others (AU-NEPAD, 2010). Similarly within the immediate Southern territories, an increasing number of SADC countries like Mozambique, Botswana and Namibia have initiated projects to measure STI activities within their territories. In 2005 the *African Ministerial Council on Science and Technology* (AMCOST) - a policy and political forum for government ministers responsible for science and technology in all member states of the African Union - adopted *Africa's Science & Technology Consolidated Plan of Action* (CPA), highlighting some of Africa's development challenges and opportunities as well as promoting the role that science and technology can play in social and economic transformation (NEPAD, 2006). Among the key challenges has been the continent's reliance on external financial support and failure to invest effectively in science, technology and innovation. The STI systems on the continent also had to contend with issues such as weak linkages between industry and STI institutions, low investment in science and technology, low numbers of researchers, declining quality of science and engineering education and the loss of scientific and technological expertise through brain drain. The CPA provided a framework as to how the improvement of STI infrastructure could respond to socio-economic challenges facing the continent as well as drive future economic growth. In December 2009 representatives of various African countries met in Ethiopia to discuss a strategic partnership under the *African Science, Technology and Innovation Indicators (ASTII)* initiative toward building shared knowledge and learning surrounding S&T indicator production and the tremendous value of STI for African development into the 21st century.

Historic datasets exist for regions across Africa, although many of these datasets are not part of a reliable data series and most, if not all of the data are not based on survey data (Frascati or otherwise) but are instead data generated as a result of partial datasets or based on estimation by national experts from within those regions. Table 1.3, below presents selected findings from the first *African innovation Outlook* publication that distinctively offered OECD guided surveys of STI indicators within participating African countries.

Country	*GERD million PPP$*	*GERD as % of GDP*
Gabon	*78.7*	*0.47*
Ghana	*120.1*	*0.38*
Kenya	*277.8*	*0.48*
Malawi	*180.1*	*1.7*
Mali †	*37.4*	*0.28*
*Mozambique *‡*	*42.9*	*0.25*
*Nigeria *†*	*583.2*	*0.2*
Senegal	*99*	*0.48*
South Africa	*4976.6*	*1.05*
*Tanzania**	*234.6*	*0.48*
Uganda †	*359.8*	*1.1*
Zambia	*55.3*	*0.37*

Source: ASTII R&D surveys 2010

*Notes: * Data do not include the business enterprise sector, † Data do not include private non-profit institutions/organizations*

‡ Data do not include the higher education sector

Table 1.3 *GROSS Domestic Expenditure on R&D (GERD) 2007/08*

Despite the dominance of South Africa within the African STI landscape, the above table illustrates the notable progress in S&T initiatives as well as measurement capabilities throughout the region.

This trend within the African and developing world context reflects global tendencies to shift the balance from resource, agricultural and manufacturing driven economies to more knowledge driven economies, and also demonstrates the awareness of the developmental leap that STI may offer emerging economies (Aubert & Reiffers; 2003, Blankley & Booyens, 2010).

A knowledge driven economy is one which recognizes the important contribution and benefit information and technology can bring toward national productivity, and actively seeks to develop systems of deriving real progress from these benefits (OECD, 1996). *New Growth Theory* seeks to understand and explain the complex interactions between knowledge and technology as a driver of productivity and competitiveness (Salvadori, 2003). This theory holds that through directed policy measures consistent long-term growth and economic benefits can be derived by stimulating innovative activities and developing the required infrastructure and human resources to extract growth from these investments (Howitt, 2007). This is emphasized by Peter Howitt in his commentary on a knowledge economy, saying that *"…economies that cease to transform themselves are destined to fall off the path of economic growth*" (Howitt, 2007). Productivity within high-technology sectors of OECD member countries has developed at increasing rates within the recent past, with the OECD estimating that more than 50% of GDP within these economies is now knowledge based (OECD, 1996). The economic and related social benefits of knowledge economies, its relation to STI, human resource development and the public understanding of science are interrelated and present a crucial roadmap toward rapid development within the developing world context.   The United Nations Millennium Development Goals (MDG's) present a global plan toward addressing issues of underdevelopment and inequality. These goals cover 8 critical areas ranging from poverty reduction, education, health care, gender rights, environmental sustainability and global economic partnerships. Significant attention has been directed toward the use of S&T and specifically information and communication technologies (ICT's) in achieving and addressing many of the related issues across the 8 MDG's.

In the South African context, the lived realities of many citizens are also highly impacted by these MDG's and related socio-economic issues described in section 1.2. The South African National Planning Commission produced the *National Development Plan 2030*, outlining the strategic vision of the government toward addressing the many South African socio-economic and developmental issues as well as opportunities to be addressed by the target year 2030. This document provides a crucial link between the Millennium Development Goals, S&T, ICT, development and growth for South Africa as well as its responsibilities across the African continent (National Planning Commission, 2012).

The DST *Ten-Year Innovation Plan* (2008) presents many of the *grand challenges* that lay ahead within the current decade toward achieving set knowledge economy goals by 2018. The key focus of the plan is to play a driving role in enhancing national productivity, economic growth and socioeconomic development within South Africa (DST, 2008). The South African Ministry of Science and Technology has highlighted four key areas of attention toward achieving these goals. These include intensifying knowledge generation (R&D and STI activities), improvements in knowledge infrastructure, measures to address the distance between research outputs and social impacts for societal benefit and increased investment in human capital development (DST, 2008). The thread linking each of these goals is based in educational enhancement toward producing a sustainable pool of suitably qualified and capable human resources. The current state of South African S&T workers has been noted as a direct barrier to future knowledge economy performance (Kaplan, 2008a and 2008b), and addressing these would be the key toward achieving the ambitious goals of the DST *Ten-Year Innovation Plan* as well as the National Development Plan. The ultimate goal of these policy directed initiatives is to enhance and secure the role played by science and technology in improving productivity, competitiveness, economic growth and address inequalities by delivering broad based socio-economic benefits to all South Africans.

South Africa has set its trajectory toward knowledge economy investment, and has made some progress toward meeting the goals set out in this *ten-year plan*. Within the post-apartheid period South Africa has made some progress toward advancing the development ideals in meeting the social and technological goals of the government. However many have also highlighted the shortcomings within this period toward recognition and future action within the S&T sector. Noted in both domestic and OECD reviews of the South African National System of Innovation (NSI), the change in focus for the South African science system, strained funding systems, lack of government leadership for S&T as well as a lack of effective policy implementation strategies are just a few of the hurdles that would need to be overcome for the effective harnessing of S&T for development in South Africa (OECD, 2007; Kaplan 2008 a & b; Marais and Pienaar, 2010). However there have also been many successes in training, development infrastructure and successful international S&T project bids during this period that cannot be overlooked. Among the other goals of the DST within the *Ten Year Innovation Plan*, include *human capital development*, which further recognizes the need for a public adequately aware of science and technology use and development (Blankley and Booyens, 2010). This would require a citizenry adequately skilled to a minimum level in areas of science and technology, in order to meet the demands of various roles within an S&T driven economy. Though this reality is still some time into the future, the DST recognises the long term requirement to effectively implement the required changes within any population and has made human capital development central to the grand challenges within the *Ten Year Innovation Plan*. Within this plan, the NSI dependencies are noted and the key areas of attention have been defined along with the enablers of development toward the set goals. Along with technology investment, human capital investment and retention is a key aspect of the *Ten-Year-Plan*. The implementation of the various strategies toward meeting this challenge is under debate however is slowly making progress toward achieving the set goals.

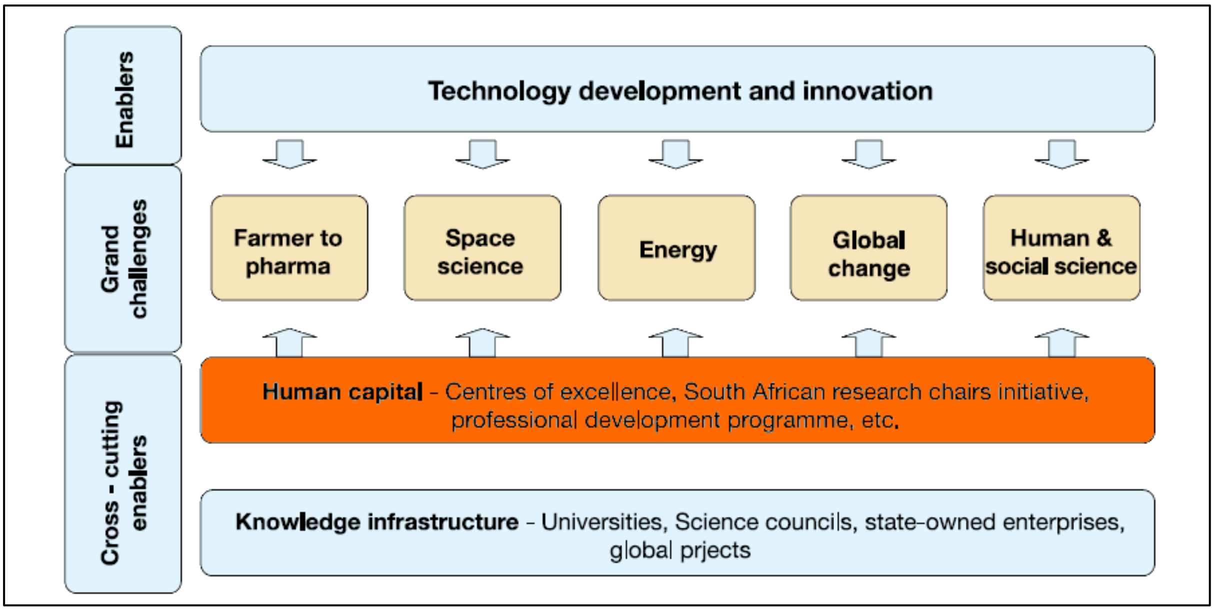

Figure 1.1: DST Ten Year Innovation Plan, 2008 (Figure 3, Page 9)

The immediate benefits of S&T, as described previously are highly valued; however it is the long-term benefits of developing S&T skills within the human capital base that will ultimately be the critical success factor for knowledge economy development (Harrison & Kessels, 2003; Moon Hee, 2005, Blankley and Booyens, 2010). A citizenry familiar with and able to engage on issues relating to science and technology is a prerequisite in order to build a healthy democracy and a strong human resources required to support the development of an effective knowledge economy (OECD, 1996, Bauer, 2000, Allum, Sturgis & Tabourazi, 2008)

Young people in Africa represent a significant portion of the population, in some regions as many as 60% (Aiwuyor, 2011, Ighobor, 2013). Historically this has been a negative feature within African demographic profiles, however as these youth populations mature and enter the workforce, it is expected that the growing economies, and increasing supply of labour within many African countries will accelerate development and productivity across the region. The median age within the Chinese population is 34.5 years old however the median age for African populations is 19.1 years old. Similarly as the populations of the current industrialised nations like China and Japan age, the demand for labour will inevitably shift toward African economies (Indiwe, 2012). The growth in technology sectors, such as wireless ICT and mobile telephone services has tremendously impacted the development space within the African region, with over 950 million mobile subscribers across the continent. Linked to this is the vast number of young people capitalising on this technological leap beyond land-line infrastructure and developing promising careers and entrepreneurial ventures based on this technological revolution (Gedye, 2012). Positive as this image is, these opportunities are still only accessible to a limited number of young people due to the current constraints that exist across the African continent, including South Africa. However as investment grows across the region employment prospects will increase for the many unemployed, though adequate training and skills would be paramount to capitalise on these on-going opportunities.

As seen with the advancement of many *post-fordist* technologies and production processes, science, technology and innovation has tremendous power to generate increased economic prosperity, create employment and drive growth within a country (Laugksch, 2001). Moreover, particularly within the developing world context, STI has the potential to uplift communities and sustain opportunities where previous underdevelopment has been a long-established limiting factor toward social change (Tongia et. al., 2005). However to meet this challenge, and the many developmental opportunities presented in its wake, developing countries and in particular South Africa must invest increasingly in the enhancement of a population able to engage with new and fast-changing technological environments. South Africa is in a unique position, being among the most developed economies, and boasting the most advanced communications and infrastructural capacity on the continent to drive the revolution of African development into the new century. Its relative position within the BRICs collective and constant learning from OECD nations offers it some developed-economy advantage within a developing world context. The internal drive to increase educational and scientific output is notable, however still greater efforts are required toward meeting the above goals. While it is abundantly clear that not learners and citizens have a desire to enter into a scientific or technological profession, a basic minimum proficiency in STI is a prerequisite to engage a new economic model, particularly in economies attempting to catch up to more developed Western economies. Having outlined the importance of science & technology as an engine of innovation, competitiveness and economic growth, it thus become imperative to develop a system for the generation of a key understandings related to the South African *public(s) understanding of science* as a non-negotiable toward effectively meeting the goals of future sustainable growth and prolonged knowledge economy success.

1.4 PUBLIC UNDERSTANDINGS OF SCIENCE RESEARCH IN SOUTH AFRICA

Laugksch (1996) has noted the general introduction of the term "*scientific literacy*" into the South African research arena, following a workshop by the South African Association of Teachers of Physical Science (SAATPS), addressing science education improvements, held in 1978. The definitions adopted by the SAATPS congress members' take into account Millers three consecutive dimensions of scientific literacy, and is likely the entry point of this term into the general discourse among researchers aligned to the education community in South Africa. In the earlier discussions related to the history and multidimensionality of South African culture, politics and public life, the period since 1978 has seen a multitude of political changes in South Africa. However these changes have not yet permeated through all socioeconomic strata in South Africa, with many still not having equal access to education, social services and adequate employment.

Adopting the concept and purpose of scientific literacy toward social advancement and economic development Laugksch notes three aims of perusing an enhanced level scientific literacy in South Africa, including an *economic* argument, *decision making* argument and a *democratic* argument. Within the economic argument Laugksch notes the requirement of a competent human resource pool required to develop and sustain a national system of innovation, a key driver of which remains effective and continuing education beyond the formal primary, secondary and tertiary levels. Moreover, beyond the theoretical scientific domains, manufacturing and technical areas also require capable human resource capital to operate evolving technically-demanding production facilities in areas such as biotechnology, nanotechnology, hi-tech manufacturing and service based industries in order to promote competitiveness and drive economic growth. Secondly, Laugksch notes the *decision making* argument toward promoting scientific literacy in South Africa. This argument string contends that at a civic and individual level, citizens are required to have a certain level of proficiency in areas involving science and technology so that effective decision making may follow from with knowledge driven evaluation processes. This is particularly important in purchasing decisions, selection of appropriate health related interventions as well as civic responsibilities and its impact on public policy. This has tremendous implications for both rural and urban development, particularly for those among the most economically marginalised. Furthermore the implications for enhanced decision making capabilities, based on increased scientific literacy also have an impact on environmental factors and planning, with increasing urban populations (Laugksch, 1996). The third argument Laugksch proposes for advancing scientific literacy relates to its importance in terms of democracy building and social development of the diverse population in South Africa. This relates to the previous point on planning and environmental factors, as well as all other areas of interaction between the public and areas of government. Public knowledge and literacy are key to enabling individuals to make effective decisions related to public policy and the overall democratic climate within a country. The competing and, at times, contradictory "scientific evidence" in numerous public debates requires a *background competency* in the various disciplines relating to the debates of the day. In the absence of this *background competency* the general public is easily influenced by the position of selected scientific actors and this reliance on "mediators of science" may result in distorted messages and decisions based on incomplete evidence relating to socially salient areas. The importance of these three key arguments for advancing scientific literacy is valid in contemporary South Africa as it was in 1996, and remains the foundational arguments around which the present study is based.

As in many other countries around the world there have been some studies conducted in South Africa investigating various aspects of public understandings of science and scientific literacy. Many of these studies have been survey based, in order to understand current public perceptions about general and specific science and technology issues. While the detailed literature review (Chapter Three) will cover a number of empirical studies, both in South Africa and in other regions of the world, the below paragraphs provides a brief synopsis of empirical work completed in South Africa.

Studies by, among others, the Foundation for Education, Science and Technology (FEST), the Human Sciences Research Council (HSRC) and the Department of Science and Technology (DST) have been conducted in order to measure public understanding and attitudes toward science and technology. Many of these studies employed the scientific literacy and public understandings of science frameworks in adopting survey instruments to measure public knowledge, attitudes and interest. Pouris (FEST: 1991, 1993, 2001) looked to study public understandings and perceptions among the South African public. He studied various segments of the population based on age, race and gender stratification, and in his later work (2001) studied the various information sources and attitudes toward science in South Africa. Adopting established measurement instruments, not dissimilar to those used in the NSF (USA) and Eurobarometer surveys, Pouris attempted to measure South Africans' civic scientific literacy and attitudes toward S&T. Despite the value of these studies and its contribution to the (then) non-existent body of knowledge within this domain of research, many, methodological questions have been raised relating to these studies (see Reddy *et al*, 2009). Key here is issues relating to the instrument validity within the developing world context, as many of the test items may not have been suitable for the South African public (as explained above). Further to this sample selection and generalisability of the results were also questioned as these surveys were administered to small subsets of the population[4]. Despite this, the use of existing tools and measures

[4] Limited geographical coverage, racial representivity and instrument validity are all points of concern in this research

of public understanding of science provides a valuable foundation to conduct further work within this area.

The HSRC conducted numerous studies on public understanding of science, along general and specific subject areas. These were administered through the various omnibus surveys of the HSRC, including the Evaluation of Public Opinion Program (EPOP), South African Social Attitudes Survey (SASAS) and a number of other client driven surveys. EPOP and later SASAS (1995, 1999) were run based on a nationally representative sample, administered to individuals 16 years and older in both rural and urban centres. These surveys collected and reported on public attitudes toward math and science, attitudes toward science and technology (using the *index of promise and reservation*) and assessed public opinion on societal benefits of scientific research. In addition to these, surveys were also conducted looking at specific issues related to public understanding of climate change (2007) and public understandings of biotechnology (2004) in South Africa.

Reddy *et al* (2009) present a summary of South African and international studies on the public understanding of science and technology and reports generally poor public literacy of science and technology in both the developed and developing world context, including for South Africa. That being said, confidence and positive attitudes regarding science and technology appear to be high, despite poor scores among South Africans on scientific literacy measures. Blankley and Arnold (2001) report that scientific interventions in South Africa need to take note of the limited scientific knowledge of the *average South African*. The root causes of these, particularly in the older generations can be explained through previous limited access to educational opportunities as discussed above. However that being said, Blankley and Arnold note that this should be considered when constructing instruments to measure public understanding of science in South Africa as local issues and understanding of the social and cultural context of South Africa may be attributing to poor scores using many of these imported measurement instruments and methodologies.

1.5 <u>OPPOSING OPINIONS</u>

The evidence and support for the concept of *scientific literacy* and *public understanding of science* has been well documented in the literature (see Chapter Two). However despite this there is a small community of researchers that have expressed various degrees of opposition and reservation as to the value and benefit of measurement methodologies, educational interventions and the stated goals of those advocating for increased scientific literacy and an enhanced public understanding of science. This section will briefly address some of the opposing opinions with respect to scientific literacy and the public understanding of science, in an effort to present as complete a rationale for the aims and scope of this study.

Chapter Two presents a detailed literature review of the theoretical evolutions in the study of the public understanding of science. Within this section various aspects related to the concept and definition of *scientific literacy* and the *public understanding of science* are presented. Paramount to understanding the concepts under discussion, as well as opposing views thereto, is an understanding of the definitional characteristics of *scientific literacy.* Laugksch (1996, 1999) proposes that views for and against the pursuit of the stated goals of scientific literacy relies on an understanding of the particular actors and interest groups concerned. Laugksch proposes five factors that influence the various interpretations of the concept, namely: interest groups, defin*itional properties*, the *nature of the concept*, *benefits of* scientific literacy and *measurement approaches*. These five factors each bring multiple facets of perspective to the discussion on scientific literacy and the particular interest group concerned provides varying interpretations of what is implied in its study. These interest groups include the *educational community*, *social scientists & researchers*, *sociologists of science* and *informal science communicators* (Laugksch, 1996). Assessing the various critical views relating to the study of *scientific literacy* and the *public understanding of science* broad alignment to these interest groups can be noted, and is discussed in the following paragraphs.

Many of the earliest criticisms of the scientific literacy movement arrived from within the educational community. As literacy, and in the case of this discussion, scientific literacy is seen as a key output of the educational community a number of criticisms have emerged from researchers within in this community. Laetsch (1987, cited in Laugksch, 1996) argues the point that the goal of education, should not be overly focused on *scientific literacy*, but should rather be to promote *generic literacy* as a goal of education. While Laetsch acknowledges the value of all forms of literacy, and recognises that not all students will go onto scientific careers, an ample knowledge of science should be acquired, along with other competencies in order to best prepare learners for post formal schooling engagements. Addressing a similar pattern of logic, Chapman (1991, cited in Reddy *et al*, 2009) argues that as the modes of production globally are shifting away from agrarian and industrial sectors, toward more management and service oriented sectors, science based education will become of little relevance to learners. In these evolving environments, Chapman asserts knowledge of science will be superseded by knowledge of technology, where in the workplace will be dominated by those that suitably adapt to the technological advances that occur. This related specifically to a capacity to adapt to changing means of doing work, rather than an understanding of *how the technology works* (Reddy *et al*, 2009). Unlike Laetsch, who recognises the value of science literacy and its relevance to contemporary and future students, in his argument Chapman questions the value and relevance of compulsory science education at schools. He asserts that as technology advances it broadens the gap between the rich and the poor, implying that the greater the ability to capitalise on advances in science and technology the greater the risk of exploitation on those that are not as scientifically literate.

Morris Shamos delivered his acclaimed book, *The Myth of Scientific Literacy* in 1995. As an educator and scientist, Shamos too approaches the discussions on scientific literacy from an educational paradigm, addressing key issues in science education and the field of scientific literacy. His position departs by addressing the perception of a *crisis in education* that emerged in the United States of America following the Sputnik 1 launch in 1957 (see Chapter Two). The crisis Shamos refers to is the multiple periods of curriculum reform within the USA educational community leading into the early 1960s, the space race and eventually the cold war. The argument is constructed to challenge the notion of a crisis in education and through discussing scientific literacy, the nature and culture of science as well as the required scientific literacy prerequisite on the general public, Shamos suggests that the goal of universal scientific literacy is unattainable and should not be the driver of curriculum reform. Shamos believes that the goal of scientific literacy, through formal education is futile, as becoming scientifically literacy through formal education creates little guarantee that students will remain scientifically literate into adulthood (1995). Similarly, as global economies had evolved, Shamos stressed that an appreciation of science and an understanding of technology, at functional levels and as a *practical imperative* would become more important toward enabling effective access and opportunity beyond the oversimplified notions of scientific literacy. It is important to remember that Shamos is not anti-scientific literacy, but rather challenges the hyper-importance attributed to it in curriculum reform initiatives in the USA. He calls for a reformulation of curriculum approaches toward building science as an important cultural and practical knowledge that leads to a required level of awareness, producing more effective and productive students and adults. Emphasising this point, the author notes that the goals should be to emphasise the process and value of science rather than school-learned scientific content. This would empower and enable citizens to engage appropriately at all levels, and to correctly interpret science communication and expert evidence in both their personal and civic responsibilities (Shamos, 1995).

Social science researchers and sociologists of science have also weighed in their concern and opposition to the over importance of scientific literacy and public understanding of science. Turney (2003) engages Greenfield (2003) on issues relating to the definition of *scientific literacy* as well as the structure of the enterprise. Turney asserts that as science has historically, and continues to be a top down information filtering process, wherein issues of power and knowledge become currency toward creating segmenting tools, based on as yet undefined criteria of what scientific literacy should be. Turney believes that the disenfranchisement of the general public with respect to science, limits their direct agency to influence the direction and speed to scientific advancement, removing social relevance and as a result influences the publics' derive to develop an increased scientific literacy. Similarly, Liu (2009) calls for a similar life-long public participation in science as a means to increase public influence and thus scientific literacy. In her paper, Liu reconceptualises the concept, as a result of what she had identified as three-key flaws in the contemporary understanding of scientific literacy. The first of these is the fact that science has been associated with a public deficit that must be corrected in the accepted top-down approach. She asserts that this approach negates the importance of a public already fairly knowledgeable, positive and capable of accusing information about science when it is situationally required or in increasingly automatic functional ways. Lui agrees with Laetsch (1987), that this attribution of a deficit, limits what and when the public will display these learned competencies and too often will moderate the internal motivation for learning science as a result. The second flaw identified by Lui is the notion of *science as a commodity*, something that is acquired and static, rather than a lifelong accumulation of knowledge. Lui highlights the publication by the American Association for the Advancement of Science, *Benchmarks for Science Literacy* (1993) as a key indicator of this flawed approach, noting the false relationship between the stated competencies in *Benchmarks for Science Literacy* and an actual attainment of these competencies in terms of scientific literacy. Thirdly, Lui addresses the idea of science as a static model and the single directionality of communication within the modern scientific culture, highlighting the flaws of the adopted top down approach. Lui endorses Roberts (2007) notions of two visions of scientific literacy by encouraging community participation and a value free notion of science communication. While this may be seen to be idealistic, as any communication may be value laden, as a result of language, culture and context, however the notion of a single direction flow of information encourages the continuation of the accepted practices of science and science communication and will do little to change scientific literacy (Liu, 2009).

The above opposing opinions on scientific literacy are predominantly based on its relative value to individuals as well as the over-importance attributed to it within the educational arena. Many of these oppositions are also located in predominantly developed economy social contexts rather than developing world communities. The benefits of scientific literacy and an enhanced public understanding of science, particularly in the developing world context is immense, where technology and science has a direct impact on quality of life, health, economic productivity and social progress. South Africa is uniquely positioned as having both developed and developing economy characteristics, and is ideally suited to responding to its many developmental and social challenged through the adoption of appropriate science and technology based solutions to leapfrog developmental stages toward economic and social development (Laugksch, 1996). Within this developmental context, the value of science, technology and indeed the promotion of literacy on these fronts present an indispensable opportunity toward rapidly addressing many of these legacy issues as a result of the previous apartheid policies. While the above views are noted, and their lessons incorporated into the approach of the current study, the value and opportunity that an enhanced public understanding of science and scientific literacy presents to South Africa must not be ignored and urges the research community to expand and enhance the discussion toward responding to these varied challenges in this young democracy.

1.6 DELINEATION OF THIS STUDY

1.6.1 PROBLEM STATEMENT AND RATIONALE

Having described in detail the uniqueness of the South African context, history and current social and scientific landscape it is evident that South Africa is at a cross roads. Future social and economic success will largely be influenced by a citizenry familiar with and informed about pertinent scientific developments. Within the current knowledge economy context and changing modes of economic production, there remains a looming crisis of a lack of adequately skilled S&T workforce. Moreover, the importance of a suitably skilled citizenry able to meaningfully engage within this changing domestic and increasingly globalised productive landscape remains key toward driving economic and social progress.

The majority of research has focused on knowledge and attitudinal measurement to varying degrees of contestation as academic consensus as to definition and meaning of key terms are yet to be achieved. Greater effort is required to understand elements influencing the public understanding of science to include *public interest*, *informedness*, *sources of information* and involvement in *engagement activities*.

With specific reference to South Africa, there remains a greater need to more fully understand the many segments of the South African public – as a national effort – in order to best respond to the multitude of issues impacted by the general public understanding and engagement with science. The National Development Plan notes the requirement of a highly skilled knowledge producing work force as well as the ever increasing technological proficiency requirement within evolving labour markets. A critical issue addressed within the literature is where this highly skilled pool of knowledge workers will develop from (HSRC-CeSTII, 2010; Blankley and Arnold, 2001, Laugksch, 2000; FRD, 1996). As indicated above, South Africa has displayed, though increasing, relatively poorly equipped number of high school graduates (Motshekga, 2011, Vavi, 2010), poor skills in mathematics and science education (IEA-TIMSS, 2007), and even fewer young people going on to S&T based tertiary education and post graduate programmes (Motshekga, 2011). However the literature also agrees that an appropriate and meticulously crafted science education policy, that is consistent with the national skills development objectives, remains a key requirement toward effectively addressing this issue. Furthermore the importance of effective science communication mediums directed at the general citizenry is a prerequisite in addressing the socioeconomic development goals as well as the human resources skills shortage in South Africa within the short to medium term (du Plessis, 2011; Blankley and Arnold, 2001; Laugksch, 1996). By understanding the social envelope of the many segments of the South African public this research aims to understand the numerous interrelated factors that influence the general public understanding and engagement with science.

The development of Indicators remains an imperative toward creating accessible, interpretable and information driven policy directions for the enhancement of the national system of innovation, through greater understanding of the interactive space shared by the general public and the scientific community. A contextual understanding of public perception, civic scientific value, knowledge and engagement with the scientific enterprise is a required precursor toward effective evidence based policy formulation that would enhance the current and future social landscape of the South African people.

This study seeks to measure public understandings of science in South Africa through a public relationship with science framework suggested by Reddy et al (2009) that takes into account science literacy, attitudes, interest, information sources and engagement activities through the diverse social context of the of the South African public. In some ways this framework is a combination of the frameworks discussed in the theoretical literature review (Chapter Three), and seeks to understand South African society within the developing world context. As Bauer *et al* (2007) notes, "*in order to grow and expand the agenda for public understanding of science research, it is important to view the various frameworks within the study of PUS not as superseding the previous frameworks, but as evolving from the preceding framework*". This evolution and progression within the understanding of the publics' relationship with science should be inclusive of the preceding research frameworks. Further the reframing of the research agenda to include the development of public understanding of science indicators highlights the requirement of a performance measurement for the national system of innovation and would be a valuable and logical next step toward expanding this area of research.

1.6.2 RESEARCH FOCUS AND HYPOTHESES

This research proposes the first systematic, demographically representative and culturally-aware survey of the South African publics' understanding of science. The research seeks to develop a baseline dataset accessing a nationally representative sample to provide greater understanding of the challenge that lay ahead as a country, determined to meet the current social and developmental challenges, with an eye toward strategic future goals. The analysis further seeks to produce a set of reliable, appropriate and accurate indicators of the South African public understanding of science. The value and contribution of this research would not only lie in the baseline data collection and development of indicators, but also in the periodic replication of this research in order to monitor public understanding of science for evaluative and policy information purposes.

The primary research question for this study is two-fold:

1. *To identify a set of indicators to measure the South African public understanding of science*
2. *Which demographic variables may best serve as predictors to the performance of South Africans on each of the indicators developed*

While the extensive literature review will in many way guide and respond to question one, later analytic work within the empirical findings of this research will inform the development of six indices to be used to measure the *South African Public Understanding of Science* (SAPUS). In responding to each of the main research questions two sub-question sets will guide the analysis and reporting of the results in this study

a) What is the Current South African Public understanding of Science (SAPUS)?
   a. What is the level of scientific knowledge?
   b. What attitudes are held by South Africans regarding science?
   c. How interested are South Africans in science?
   d. How informed are South Africans about science?
   e. What are the main information Sources regarding science?
   f. Which are the most frequented Science engagement activities in South Africa?

b) What predictor variables best explain SAPUS scores?
   a. How do SAPUS scores vary according to various demographic segments?
   b. Which demographic variables show predictive value in explaining SAPUS scores?

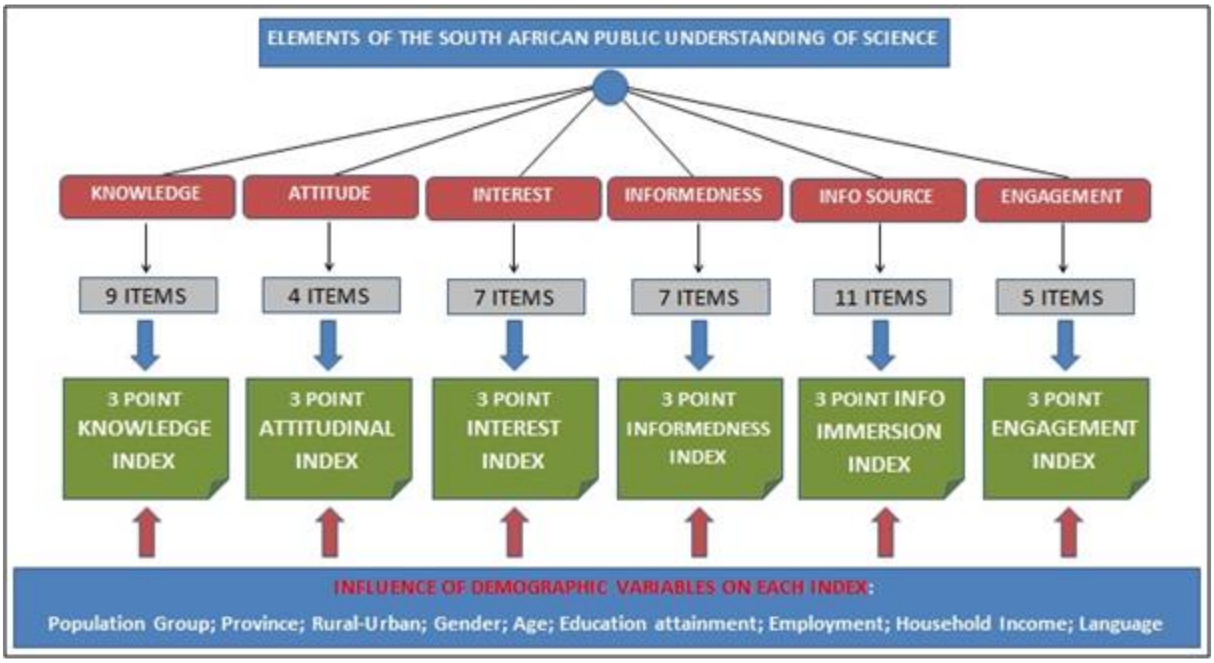

Figure 1.2: Conceptual framework for investigating the South African Public Understanding of Science

Figure 1.2 presents the conceptual framework for this study indicating the six elements under investigation. The study employs a survey research methodology using a quantitative questionnaire. The questionnaire contains six parts, each relating to an individual element represented in Figure 1.2. Each element has a number of items within the survey instrument that is used toward developing each of the six indices. In total the questionnaire contains 43 items each accessing particular facets of the SAPUS elements under investigation. It further includes a number of demographic classification items that are at times in the analysis considered to be independent variables influencing the respondent score on each index. The method employed provides an assessment of a large number of individuals, from across the nine South African provinces and yields a significant amount of data. The data is useful toward understanding the distribution of knowledge, attitudes, interest, informedness, information sources and attendance at science engagement activities. Moreover the data and its related demographic variables allows for greater analytical possibilities within and across various socioeconomic classifications. The data yield is massive and as such the analytical framework for this study is deliberately limited in scope to allow for a more detailed investigation of indicator production, however does reveal the potential for future research possibilities.

Research Hypotheses

A number of research hypotheses are tested in this study. These hypotheses (listed below) were generated based on our review of (mostly) South African studies over the past three decades. The review is presented in Chapter Three (Section 3.2.4).

The hypotheses are listed below according to the six main research themes of the study:

<u>**Knowledge of Science**</u>

Hypothesis 1a: *South Africans are likely to record low scores on an index of scientific knowledge*

Hypothesis 1b: *South Africans of different demographic categories (race, education, income) are likely to record different levels of knowledgeability about science*

<u>**Attitudes to Science**</u>

Hypothesis 2a: *South Africans are more likely to hold positive than negative attitudes towards science*

Hypothesis 2b: *South Africans of different demographic categories are likely to differ in their attitudes towards science*

<u>**Interest in Science**</u>

Hypothesis 3a: *South Africans are more likely to record low than high levels of interest in science*

Hypothesis 3b: *South Africans of different demographic categories are likely to differ in their levels of interest in science*

<u>**Informedness about Science**</u>

Hypothesis 4a: *South Africans are more likely to record low than high levels of informedness about science*

Hypothesis 4b: *South Africans of different demographic classifications are likely to differ in their levels of informedness about science*

<u>**Science Information Sources**</u>

Hypothesis 5a: *South Africans overall are more likely to favour "old technologies" (Radio, TV and Print) compared to "new technology" (online) information sources*

Hypothesis 5b: *South Africans of different demographic classifications are likely to differ as far as their preferred sources of science information are concerned*

Science Engagement

Hypothesis 6a: *South Africans are more likely to record low than high levels of attendance at science engagement activities*

Hypothesis 6b: *South Africans of different demographic classifications are likely to differ in the frequency of attendance at science engagement activities*

1.6.3 STRUCTURE OF THESIS DOCUMENT

This document is comprised of 12 chapters, each covering a particular aspect of the line of reasoning for the development of indicators to measure the South African public understanding of science. Chapter Two presents the first part of the extensive literature review. This chapter covers aspects relating to the theoretical development of scientific literacy and the study of the public understanding of science. Specifically this chapter addresses the historical development of the field, the main frameworks as well as a discussion on definitions and the establishment of consensus as to what should be measured.

Chapter Three continues the literature review by presenting a broad review of empirical work undertaken within the last 50 years. The review considers the global developmental divide that exists across countries and begins with studies conducted in the developed world followed by studies undertaken within the developing world context. Beyond the major OECD, National Science Foundation and EuroBarometer surveys, this section also presents some of the varied analysis performed within these surveys. The review of empirical work from within the developing world includes China, Malaysia, and India and concludes with a review of key South African studies within this field. The last section, Chapter Three particularly highlights the dearth of empirical and theoretical work specific to the South African context and highlights the contribution this thesis hopes to make.

Chapter Four introduces the methodological considerations employed within the conceptualisation, design, development and implementation of this study. It initially revisits the discussions on science indicators and indicators of scientific literacy and the public understanding of science. Taking the content of section 1.2 (above) into account this chapter then establishes the link between the South African social context and the value of nuanced PUS indicator production, rooted within the multidimensional South African context. Chapter Four further discusses the development of the research instrument employed in this research as well as the implementation requirements and schedule. The chapter concludes by presenting selected data outputs and data requirements for indicator development.

Chapter Five through to Chapter Ten presents the results and analysis of the fieldwork phase. Each results chapter is complemented by a related Appendix chapter containing additional analysis and background information. This section of the thesis presents a summary of the demographic characteristics of the survey sample and population description. It continues to build the demographic profile of the sample, defining some of the data reduction strategies employed within the analysis. It goes further to present the analysis and the findings for each of the hypotheses discussed above and the result presented at the appropriate point.

Chapter Eleven, following from the analysis in chapter five though ten, presents each of the six indices created by discussing the item selection; an examination of the empirical relationships between the items and selected other variables; Index construction and scoring as well as index validation. The results by selected demographic variables are also presented for each of the 6 indices. Chapter Eleven concludes with the presentation of the multinomial logistic regression analysis investigating which demographic variables could be considered predictors to the outcomes of South Africans on each of the six indicators developed.

Chapter Twelve presents the summary and conclusion of this research. It specifically discusses the results of the analysis in chapters five through to chapter eleven, with a focus on the key demographic variables that predict performance on each of the six indices produced within this study. The chapter continues by revisiting each of the hypotheses proposed within Chapter One and concludes by proposing recommendations for future research within this area in South Africa. A closing recommendation is proposed that highlights some of the key requirements toward the development of a composite indicator measuring the *South African Public Understanding of Science*.

1.6.4 VALUE OF THIS RESEARCH

The research resources and outputs developed from this study will be of increasing value to researchers, policy makers and science communicators (in both the private and public sector), as South Africa continues its shift toward a knowledge-based economy. The results are also aimed at serving the more immediate need of policy makers and science communicators in addressing the crucial gaps in particular demographic clusters regarding certain domains of S&T research (DST, 2008). Further understanding and the development of tools to further study the public(s) relationship with science and technology will go a long way toward not only building a more inclusive S&T system, but also address the crucial social, human and democracy building potential that lies in understanding this, often complex, interaction between science & technology and the general public(S) (Reddy *et al*, 2009).

Chapter Two

Literature Review: Theoretical Evolutions

Like other relationships, science and society is not just a matter of distance, but also one of quality. We need to explore in some detail how the different groups, maybe in equidistance from science, relate to its achievements and propositions.

Martin Bauer (2009)

INTRODUCTION

As described in Chapter One, science and technology influences the daily lives of most every human in direct and, increasingly, in indirect ways (Reddy, *et al*, 2009). All technologies, products, public records, access to information, healthcare and learning are in some implicit or explicit way grounded within a science and technology derived solution. As already discussed, the pervasive nature of science and technology impacts at all levels, stimulating social and economic growth, and is therefore salient for academic enquiry (Royal Society, 1985). Though most people might not be aware of this daily upstream link with the world of science and technology, understanding and advancing the study of the relationship between science and the public is vital for the ambitions of South Africa and its people (DST, 2007).

Science has considerable potential to contribute to national growth, yet much of this potential remains latent due to the current relationship between science and the public (Burns *et al*, 2006). However, there remains great value in understanding and enhancing the relationship between the public and the scientific community toward harnessing the inherent social and developmental benefits of science and technology for growth and development. South African society, as discussed in Chapter One, is highly stratified. It is this stratification - in terms of science and technology knowledge, attitudes and access to information - that makes understanding the levels of *scientific literacy* particularly difficult to measure within the social context of contemporary South Africa (HSRC, 2004).

Despite the apparent difficulties with regard to measurement, understanding the nature of the relationship between science and the public is extremely important, particularly for a developing economy like South Africa. A positive relationship between science and the South African public will promote the goals of the knowledge economy. As a more informed and educated public acquaints itself in the domain of science and technology, it will be more open and best adapted to the changing modes of production within a modern knowledge economy context (DST, 2008). Further to this, a public more informed and interested in science and technology issues will be in a better position to provide the crucial human resource base required to build this knowledge economy, thereby enhancing employment and social development in the long term (Reddy et al, 2009). The value of this relationship between science and the public is further strengthened by the notion that a society more informed is thereby more able to be actively involved in decision-making and policy formulation and is therefore a democratically active society, thus furthering the ideals of democracy and nation-building through developing understandings of this relationship (Laugksch, 1996).

The field of Public Understanding of Science (PUS) is still evolving, and since the 1960s has attracted much debate as to the relevance of its impact on society. Studies of this nature aim to explore the measurement and measurable impact on development, as well as the many constructs within the public understanding of science research domain (Nowotny, 2001; Bora & Heiko, 2006; Reddy et al, 2009). Despite this, as an emerging field of study in South Africa, with valuable research having been conducted - which at times led to intense debate regarding methodology and practice - its relevance and importance within the developing world context cannot be overstated (Pouris, 1991, 1993, 2001; Blankley and Arnold, 2001; HSRC, 2004; StatSA, 2005).

2.1 SCIENTIFIC LITERACY AND THE PUBLIC UNDERSTANDING OF SCIENCE[5] - HISTORICAL OVERVIEW

The cultural roots of *scientific literacy* go back to the introduction of modern science into Western civilisation, approximately during the 16th century. Sir Francis Bacon, Thomas Jefferson, Benjamin Franklin and many preceding them noted the pervasive contribution science and its study may offer society and humanity as a whole (Hurd, 1998). Much of the modern history of public understanding of science leading to the *scientific literacy* movement in the early 1980s was and continues to be linked to educational curricula reforms in relation to national priorities and the competencies expected of school leavers. A brief synopsis of the period predating the 1980s is presented below to provide some historical context for the discussion on the three paradigms of research on *scientific literacy*.

Despite the extensive and at times controversial history of science itself, much of the history of contemporary Western science education is centred within the European and American social envelope. As a direct impact of colonialism in South Africa, large elements of this history and subsequent structures were inherited and incorporated into the South African science and education system, and further racially impacted due to the influence of the government and the apartheid system. Much of the historical context described below is directly due to the evolution and study of European and American science policy, political and social events in those countries, and their influence on educational policy. The result of these policies, political and social evolutions directed

[5] In this sections *public understanding of science* is referred to by its earlier *umbrella* term *scientific literacy*

much research and theory development in education in general, but also in science and technology policy, and has served not only to guide research in the United States and Europe but been adopted and critically assessed by the global research community active within this field.

Before the mid-19th century, due to early opposition to science entering the school curriculum, much of early, colonial-styled scientific learning was centred on museums, universities and academies of science, as specialist areas of study and inquiry. Formal science instruction only became part of the school curriculum in Europe and the USA during the latter part of the 19th century. William Sharp, the noted British surgeon and physician is credited in 1850 as being the first formal science teacher in British public schools after developing a model for the instruction of science in the school curriculum (Power, 1897).

Despite the initial insufficiency of science education within the school curriculum, it was recognised by practicing scientists that, notwithstanding the dominant influence of the humanities in educational syllabi of the time, an incorporation of the sciences into curriculum may have a profound impact on the future effectiveness of the learner as a productive member of society (DeBoer, 2000). Shamos (1995) notes the influence of Herbert Spencer (1855) and Thomas Huxley (1880), among others, in igniting public interest around the issue of this dominant view of 19th century education, which was primarily concerned with literature and the humanities. Their classic essays note the potential value of science education for the long-term benefit to the individual learner and to society. Though their view was not widely adopted at the time, its value has come full circle and is acknowledged in contemporary education, where scientific subjects occupy an important role in modern educational curricula.

In the late 1890s, a critical theme emerged in educational philosophy as a direct result of the impact of science and technology on contemporary society of the time. The influence of science in imparting the essential intellectual training beyond deduction and toward more induction-centred reasoning fostered a more independent approach to education and inquiry. It was further postulated that this revised philosophical approach and its impact on education would develop the *empowered-student* and the resultant outcome of educational attainment (DeBoer, 2000).

The dawn of the 20th century saw the emergence of the first of three major education reform movements in the United States (Shamos, 1995); the first of which appeared in 1916 with John Dewey's legitimisation of the study of science in the school curriculum and the proposal of the promise of independence of thought, learning and action it presented students. Dewey referred to the evolution of this 'independence' as the development of *habits of the mind* (Dewey, 1916).

Dewey's work influenced much of the early 20th century thinking about education, and particularly science education, with its many references to life experiences, independent investigation and the advancement of society.

Between 1916 and the late 1940s, the second period of reform began with a number of United States commissions established by the National Education Association (USA) with the mandate to develop educational curricula with an extended theme of making education relevant to activities of daily life, rather than purely as a study of specific scientific subject matter, of value to both future scientists and non-scientists (DeBoer, 2000). The focus of the *relevance to daily life* criterion for science education related specifically to the goal of science teaching and the impact on social progress, cultural patterns and the life of the individual within society (Hurd, 1998). With the war years (1939-1945), the period following 1942 saw massive progress in many scientific fields, notably nuclear energy, space exploration, technology, communication and human biology (Laugksch, 2000). This scientific progress was driven for the most part by the need, particularly in the USA and Europe, for reindustrialisation, and the desire to remain globally significant both militarily and economically through harnessing of science for the purpose of accelerating progress and national growth (DeBoer, 2000). A major theme that emerged in this period was the challenge to ensure that science education reforms keep pace with the progress achieved in these scientific areas (Shamos, 1995).

These challenges and reforms within education were aimed at ensuring that, along with harnessing the brightest scientists within research and industry, society also developed a highly educated citizenry that understood the scientific process in this period of great progress and public investment in the scientific enterprise (DeBoer, 2000). In October 1958, Hurd proposed that the new goal of science education should be to increase *scientific literacy*[6] within society through enhanced educational approaches to teaching science in schools. Hurd noted the requirement of a balance between the drive to develop the critical scientifically competent workforce while simultaneously inculcating an appreciation for the cultural value and intellectual process of scientific discovery (1958, 1998). Hurd's ideas about *scientific literacy* had gained significant traction by the early 1960s, with Waterman proposing that 'Progress in science [depended] to a considerable extent on public understanding and support of a sustained program of science education and research' (1960).

By the time US president John F Kennedy delivered his famous "*We choose to go to the moon*" speech, launching the USA's goal of landing a man on the moon, the Russians had already launched the satellite Sputnik-1 in 1957 and Vostok-1 in 1961, successfully placing a human being in orbit around the earth for the first time in history (NASA, 2013). Despite the generally positive public

[6] Defining *Scientific Literacy is a theme that will be discussed in the next section of this chapter*

support for the United States space program, increasing concern emerged about the ability of science education to maintain pace with scientific advancement and a changing technology landscape being imposed on society during that time (Laugksch, 2000). This concern from within American society sparked significant reform in science education to address perceived low levels of *scientific literacy* within that society. Similarly, in Europe and particularly in the United Kingdom, the late 1960s saw a period of increased public investment in science and education in response to many reforms in policy (see Edgerton, 1996). This was yet another catalyst period in the history of *scientific literacy*, initiating the third science education reform period in the 20th century (Shamos, 1995).

Laugksch (1996), drawing extensively on the work of Roberts (1983), cites the period between 1960 and 1980 as a particularly important time in the history of *scientific literacy*. He notes that within this period, understanding of what the meaning and definition of scientific *literacy* is and should be, attracted much debate. The work of this period gave rise to an array of definitions, to a point where Roberts concluded, '…scientific literacy virtually came to be an umbrella concept to signify comprehensiveness in the purpose of science teaching in schools' (Laugksch, 2000 p. 73).

The economic conditions in the Western nations in the 1970s and early 1980s juxtaposed the emergence of economic and industrial powers in the Far East, which again brought American (and British) economic competitiveness to the fore (see Japanese post-war economic miracle). With science and technology recognised as a key driver of economic development and growth, American science policy highlighted the decline in research output and thus correlated this with a declining economic performance during this time. The focus on American research capacity and competitiveness highlighted what Shamos (1995) calls a 'perceived crisis in science education'. This encompassed what was seen to be 'an inevitable' education and human resource shortage in the near future, as well as its implications for development, competitiveness and economic prosperity.

The 'crisis' reignited interest in *scientific literacy* research in the early 1980s in both the United States and Europe. On their *Project* 2061, including the publication of 'Science for All Americans' (1989), the US National Science Foundation and the American Association for the Advancement of Science (AAAS) collated leading multi-disciplinary thinking on the inputs required to improve *public understanding of science* for the next generation of school leavers. In addition, the publication of the Royal Society Report, *The Public Understanding of Science* (1985) further intensified European interest and research within this field. This period is the focal point of what is now commonly referred to as the three (3) paradigms used in *public understanding of science* research. These research paradigms are also referred to as the d*eficit models* of *public understanding of science* research, as each ascribes a deficit of particular traits to a particular actor or groups of actors within the research sphere (Bauer *et al*, 2007).

Period and Research Paradigm	Attribution deficit	Research Areas
Science Literacy 1960s onward	Public deficit of knowledge	Measures of literacy, Educational policy
Public Understanding of Science After 1985	Public deficit of attitudes Education	Knowledge and Attitudes Attitude formation and change
Science and Society	Trust deficit, Expert deficit, Public confidence	Public participation, Mediators of science, Evaluations of impact

Table 2.1: Chronological Period and Research Paradigm: Adapted from Bauer, Allum, & Miller; 2007 page 80

Each of these paradigms will be briefly explored in the following section, highlighting its development, key points, criticisms and relative contribution to the contemporary consideration of the *public understanding / relationship with* [7] *science*.

The study of the public's understanding / relationship with science has changed over time; as a result the methods and frameworks employed in furthering the development of this field have transformed with the debates of the day. The various research frameworks within this discipline have all proposed methodological improvements and wide-ranging epistemological critiques on the preceding approach. However, Bauer *et al* (2007) have presented the argument that rather than assume each of these paradigms supersede each other, they should be seen on a continuum of theoretical evolution, complementing each other, each building the understanding and expanding the agenda of public understanding of science research into the future.

2.2 MAIN FRAMEWORKS FOR THE STUDY OF THE PUBLIC UNDERSTANDING OF SCIENCE

2.2.1 SCIENTIFIC LITERACY

Despite the extended history of interest in science education and its influence on the study of the *public understanding of science* (PUS), the main stimulus of the modern PUS movement reached critical mass after the 1960s and particularly in the 1980s. The epicentres of theoretical and research progress in this domain were primarily within the United States and the United Kingdom, though during that time a number of scholars from further afield had also contributed to the foundations of this research area (see Roberts, 1983). As discussed previously in this chapter, during the mid-1950's and early 1960s there was a crisis of legitimacy for science in the United States, where the scientific community had to rally support from the public for science and technology projects, particularly

[7] Relationship is included here as a result of the changing focus in the field of scientific literacy / public understanding of science

those of national importance (Laugksch, 1996; DeBoer, 2000; Wolf & Barton, 2004; Bauer *et al*, 2007). Public support would ensure government support for these projects and therefore continued or enhanced funding flows as a result. Public support is however dependent on a citizenry equipped and empowered to see the value and engage in debates pertinent to the scientific enterprise and its influence on society. The corollary, from the perspective of the scientific community, was the required citizenry, knowledgeable and supportive of the work of the scientific community (Miller, 1983). In the 1983 special issue of *Daedalus,* the journal of the American Academy of Arts and Sciences, a number of academics, teachers and scientists noted the deplorably low levels of scientific literacy among American citizens, and forewarned of the impact this may have on the economic and political future of the country. The concern raised, and the ensuing questions posed to the academic and educational institutions, launched the scientific literacy movement in the United States of America, giving rise to renewed efforts to address scientific literacy within that country's population (Lewenstein, 1992, in Turner, 2008).

Similarly, in the United Kingdom, the publication of the Royal Society Report on *The Public Understanding of Science* (1985)*,* while sharing certain points in common with the American movement, noted with grave concern another dimension of the science/public relationship. The report committee, chaired by Dr W. F. Bodmer, highlighted the traditional relationship between the scientific community and the general population, in particular, the diminishing public support for the scientific enterprise within the United Kingdom (Turner, 2008). This social pressure on the political climate naturally led to funding constraints and, ultimately, reduced scientific output during this time (Noble, 2013). Among other recommendations, the committee called for increased communication between the scientific community and the general public, highlighting the role to be played by both industry and the media toward meeting this goal. The scholastic fraternity were also encouraged to reform science education, encouraging mandatory science instruction to all learners at the primary school level (Royal Society, 1985). With the advances in society, and the increasing human interaction with science and technology during this period, it was deemed necessary to develop an understanding and facilitation of the relationship between *science* and the *public*, which led to the development of the *scientific literacy* framework for conducting research during this time.

During the initial period (1960-1983), research on scientific literacy remained relatively uncoordinated, and the development of precise measures didn't emerge until the mid-1980's. Jon D. Miller referenced the 1979 National Science Foundation's Science and Engineering Indicators Survey in his 1983 paper, and from his analysis, reported relatively low levels of scientific literacy in the American population. A tenuous agreement resonated within the research fraternity with respect to the perceived low levels of scientific literacy within general populations as well as the need to develop an understanding on how to accurately define, measure and address public scientific literacy. Regardless, the scientific communities on both sides of the Atlantic faced the challenge of locating agreement on the precise definitional aspects that surrounded scientific literacy and its relationship to measurement (Miller, 1983; Shamos, 1995; DeBoer, 2000; Laugksch, 2000; Bauer, 2007; Holbrook & Rannikmae, 2009). Prior to this stage, extensive work had been published in the area of scientific literacy, as previously discussed. Much of those discussions related to education curriculum reform as well as areas of definition related to scientific literacy[8]. Miller contends that the most salient point of misunderstanding was in relation to the meaning of literacy: what it meant to be literate; whether it was having received formal education in a specific subject matter or having the basic knowledge to read and write (Miller, 1983). While much of the historical debate related specifically to the relevance of science instruction within the increasingly specialised education domain (see Huxley, 1880; Arnold, 1882; Snow, 1959; Wollheim, 1959; Trilling, 1962 and Green, 1962), Miller puts forward the view that all of these, whilst discussing the meaning of being *literate* and (or) *learned*, fail to efficiently discuss the effective communication and learning of science within a contemporary social context. In his 1983 landmark paper, Miller explores the historical debate surrounding the definition of *scientific literacy,* noting Gabel's (1976) assertion that *scientific literacy* by that time had come to mean so many things that it defined everything in relation to the assumed value of science education, but at the same time could not be of any use theoretically or practically (Laugksch, 1999). Though a constant definition of scientific literacy is not agreed upon universally within the academic community, noted scholars within this field do agree that the work of Miller offers the most consistent definitional characteristics over time (Bauer *et al*, 2000, Burns, 2003, du Plessis, 2011).

Miller (1983, 1987, 1998) defined *scientific literacy* to include three (3) key dimensions to be met at a minimal level: a) Knowledge of scientific facts, b) an understanding of scientific methods and c) an understanding of the relationship between science and society. The main thrust of this research approach is that a scientifically literate person should be able to understand basic scientific and technological terms, facts and methods. It goes further to highlight the importance of an appreciation of the outcomes of scientific activities and the value this extends to society. Miller went on to note the importance of a public capable of identifying valid scientific fact, and the rejection of superstitious and pseudo-scientific beliefs not derived from scientific methods (e.g. astrology, numerology). Bauer, *et al* (2007) notes the double analogy when understanding scientific literacy as both the drive for basic literacy through education as well as the requirement of that literacy toward

[8] Will be revisited at a later point in this chapter

becoming a democratically active citizen. Laugksch (1996) further emphasised these analogies under his three (3) arguments for the acquisition of scientific literacy, namely, the economic benefit, the decision-making capabilities as citizen and consumer as well as the democratic and social application of the skills acquired in the pursuit of both basic and scientific literacy.

The key research focus in the scientific literacy paradigm is the psychometric testing of factual scientific knowledge (Bauer *et al*, 2007). This is achieved through the use of quantitative, usually survey-based, methodologies. More recently qualitative methods have also been applied to introduce a greater degree of reflexivity (Wynne, 1991; Bauer, 2009). Applying the three (3) dimensions of scientific literacy, Miller used the 1979 National Science Foundation survey, which included the required test items to develop the first estimates of national scientific literacy in the United States under a single measure (Miller, 1983). Laugksch identified three (3) distinct measurement traditions in scientific literacy/public understanding of science research, including the *sociological approach*, *science educator's approach* and the *social scientific approach* (Laugksch 2000). The last of these is predominantly concerned with understanding and describing trends within a given population with respect to - in the case of scientific literacy - acquisition of scientific knowledge, specific attitudes toward science and its impact on society as well as societal support for science and issues of scientific significance (Laugksch, 1996). Researchers invested in this tradition of scientific literacy measurement have historically adopted these quantitative approaches to measurement using large scale surveys, standardised questions and produced composite measures as indicators of scientific literacy within a given population (Laugksch, 2000).

Miller constructed research items and instruments that isolate the basic elements of scientific literacy for the given population. The United States National Science Foundation (NSF), initially, and later, the Eurobarometer surveys, employed these measures of scientific literacy in order to develop early indicators in the area of scientific literacy research, and they have subsequently been adopted by many countries in Europe and the Far-East (Bauer, 2009). These measures have been revised over time and distilled to its essential components: knowledge of scientific *facts* and *methods*, though it is still debated to what degree these measures have been adapted from Miller's original definition (Beveridge & Rudell, 1988). Millers' measures of scientific literacy continue to be used today and provide useful measures as to the level of scientific literacy, despite the various critiques regarding the international comparability and cross-cultural compatibility of these measures in different settings (Bauer *et al*, 2007, Raza *et al*, 2002).

This Scientific Literacy model presents the argument that the public is by default *deficient* regarding knowledge of science and technology facts, methods and policy issues, when compared to the scientific community. Assessments of scientific literacy under this model, employing quiz-like test items to produce composite measures of scientific literacy, usually highlight these deficiencies within given populations. It was therefore concluded from this that a scientifically illiterate public would not be able to fully participate in effective decision making and policy decisions, nor adequately appreciate, nor derive benefit from science and technology due to these measured deficiencies in scientific literacy (Burns *et al*, 2003). Miller proposed that it is the responsibility of the scientific community to correct this deficit, as lack of knowledge may lead to negative appreciation for the value of science and thereby negatively impact on the progress of the scientific community in the long term (Miller, 1983).

Scientific literacy became known as a *deficit model(s)* of public understanding of science research, attributing this *deficit* on the public, as a means to attract attention to the education agenda (deBoer, 2000). However, others have argued that these measures only consider formal scientific knowledge, excluding *informal*, *indigenous* or *practical* scientific knowledge, thereby not accounting for cultural variables that may impact on *measured scientific literacy* (Bauer & Durrant, 1997, Raza *et al*, 2002). This lack of cultural reflexivity highlights an inadequacy within the scientific literacy paradigm, particularly when it is considered in a differing cultural context, as the constructs may be seen as not sufficiently sensitive to accurately measure scientific literacy particularly in the developing world context, given variances in education and cultural distance (Raza *et al*, 2002). These issues have been addressed through the use of item analysis and item response theory to ensure validity and appropriateness of test items within scientific literacy assessments (see Miller and Pardo, 2000).

A further criticism of the scientific literacy paradigm is that as a framework for conducting research it assumes a positive relationship between *public knowledge* and the *public relationship with science*, and also does not make allowances for a negative relationship between the public and science following knowledge acquisition (Reddy *et al*, 2009). This is further endorsed by Raza, Singh and Dutt's statement (2002) that individuals may have '*conflicting and coexisting beliefs about the same subject matter simultaneously*', and that this, together with the exclusionary nature relating to the belief in *superstitions* may potentially render a large portion of the religious / alternative beliefs population as scientifically illiterate according to Miller's definition. The deficit adopted under the scientific literacy framework presupposes a power relationship between science and the public and in many ways it soap-boxes the scientific community, where it appears to be public-focused but instead serves an education agenda through one-way communication channels. This places the scientific enterprise at risk of alienating the public from science, which is counter to the ideals of the public understanding of science research community (Sturgis & Allum, 2004).

The scientific literacy framework was created to develop a baseline measure regarding the extent of public knowledge of science and technology subject areas (Miller, 1998). This remains valuable today, within the context of the education and national policy agenda that calls for more directed educational interventions to combat this imposed *'scientific literacy deficit*'. Naturally, this will have the related socio-economic and democratic implications for a given population and, through effective research and action, when interpreted within a specified social context, may deliver a tremendous positive benefit to both the research community and all members of society.

2.2.2 PUBLIC UNDERSTANDING OF SCIENCE

The period following the early 1980s and the landmark work of Jon Miller (and others), stimulated many debates, and as a result considerably advanced the body of knowledge generated in that time (Evans and Durant, 1989; Bauer et al, 1994; Laugksch, 1996; Durant, 1999; Miller, 2001; Bauer, 2007). While Miller and his counterparts were popularising and exploring the many research dimensions of scientific literacy in the United States of America, in the United Kingdom the political, social and institutional aspects of science were under increasing scrutiny (Gregory, 2001). By the early 1980s, Britain under Margret Thatcher was experiencing many economic challenges. Key among these were an initial slowing of economic growth, civil unrest related to high unemployment, privatisation of state owned companies as well as a general reduction in public spending (Osbourne, 2013). This was of particular concern to the scientific community as these political and social challenges all had direct consequences for the advancement of science within then contemporary Britain. By the middle of the 1980s, science and technology-related R&D (Research and Development) had developed an industrious private sector component, responsible for a considerable number of projects. With a significant component of public-funded R&D projects under private control, public participation and information on state-spending regarding science and technology was generally low (Gregory & Lock, 2008, in Reddy *et al*, 2009). Similarly, following the immediate post-World War 2 period, British public attitudes toward science had dramatically shifted from a sense of 'promise and optimism' to one of 'disappointment and hostility', and by the 1980s there was a general sense of ambiguity within the British population related to perceptions of science (Miller, 2001). Scientists themselves began to operate increasingly in a 'cocoon mentality', predominantly communicating within their own circles of specialisation, maintaining the medium of the highly specialised scientific journals and symposiums as the preferred transmitters of scientific discoveries and discussions - further alienating the public from developments within the scientific community (Ziman, 1991). This, allied to the socio-political climate of the day, raised many public concerns regarding science and technology spending under Thatcherism. The scientific community almost immediately responded by trying to understand the general public's views related to science and technology issues and to find ways of improving the relationship between *science* and the *public*.

In 1985 the British Royal Society, under the chairmanship of Dr W. Bodmer, published a report entitled *The Public Understanding of Science*, wherein it described what the committee of eminent experts distilled to be the essential elements of the relationship between the scientific community and the public (Royal Society, 1985). In the Royal Society report, Bodmer and his colleagues had put forward the opinion that the contemporary public-science relationship had left the scientific community increasingly vulnerable to critique from the public. This placed future support and scientific advancement at risk of stagnation due to changing public opinion of the perceived value and contribution science - in particular, publically financed science - delivered to society (Royal Society, 1985; Miller, 2001; Bauer, 2007). Following the Royal Society report, the Committee on the Public Understanding of Science (CoPUS) was established in the United Kingdom to facilitate and develop schemes to understand public attitudes to science and enhance the flow of knowledge and communication of science toward the general public.

Following the Royal Society report in 1985, *Public understanding of science (PUS)* emerged as a research paradigm. Though it shares many concerns with the scientific literacy framework, its main focus is on understanding public attitudes to and interest in science, and how this relates to scientific literacy and its overall impact on the science/public relationship. The *public understanding of science* framework holds that the public is not positive enough about science, and this (presumed) negativity had become a point of concern for science institutions and the scientific community, particularly in the United Kingdom, but also in other parts of the world (Durant, 1999). For researchers working within the *public understandings of science* research paradigm, this new focus expanded the research agenda from more than just measuring literacy, to one that also included understanding *public attitudes* and *interests* relating to science and technology (Ziman, 1991). Hence, science communication became of increasing focus as the quality of communication was seen to be highly influential in developing *positive* attitudes toward science and technology.

The research agenda became increasingly concerned with the development of reliable measures to assess attitudes toward science. Daamen & Van der Lans (1995), in particular, noted the scientific interest in understanding the relationship between *general* and *specific* attitudes[9]. Others too have noted the relationship between general and specific attitudes and the complexity it brings to the science-public relationship, its measurement and effective means of developing enhanced outcomes for public involvement (Pardo and Calvo; 2002). With the advent of the *public understanding of science* framework, the multi-dimensionality of the public's relationship with science is acknowledged in some degree, as it takes into account not only knowledge, but also attitudes toward and interest in science and technology as key elements in the public-science relationship (Laugksch, 1996; Bauer, 2000; Bauer 2007). Both the National Science Foundation (*Science and Engineering Indicators*) and the European Commission (*Eurobarometer*) studies now include attitudinal measures and interest-in-science evaluation elements from the *public understanding of science* framework in their large scientific literacy surveys in the United States and Europe, respectively.

The major shift away from research under the scientific literacy paradigm is that - where *scientific literacy* is a qualifying measure - where one is either 'scientifically literate or not', within the *public understanding of science* paradigm a continuum is established where the results are expressed as a public being '*more or less knowledgeable*'. This was seen as a more constructive and less offensive research output than previous measures (Evans & Durant, 1989, in Bauer 2009). Ziman (1991) outlines the early period of the public understanding of science research framework, noting in particular that the preceding scientific literacy framework offered little interpretative value to researchers interested in understanding the complex nature of the public-science relationship. Where the scientific literacy framework adopted the simple axiom, *the more people know, the more they would be supportive of science*, the *public understanding of science* framework questions this simple linearity and highlight the multi-dimensionality of the public relationship with science. Bauer, Durant and Evans (1994) present an examination of varied international research studies to challenge the assumption of a simple linearity in understanding the science-public relationship. They conclude that the simple linearity, assuming that more knowledge leads to more interest and ultimately more positive attitudes toward science, is inadequate in light of the research findings suggesting that greater information acquisition may have multi-dimensional influences on attitudes related to various scientific areas (Bauer, Durant & Evans; 1994, Allum, Sturgis & Tabourazi; 2008). These considerations advance the study of the public understanding of science toward a more contextual approach, understanding the multifaceted elements active in attitude development and how this influences public perceptions of scientific investigations and outputs (Miller, 1991).

[9] General attitudes refer to attitudes toward science in general, while specific attitudes refer to specific scientific issues (climate change, biotechnology etc.).

The period following the Bodmer report (between 1985 and 1990), had dramatically influenced the science-public relationship in Britain (Durant, Evens & Thomas, 1989). With the establishment of the Committee on the Public Understanding of Science (CoPUS), changing low levels of scientific literacy and developing positive attitudes toward science were among the primary aims of PUS researchers (Miller, 1991). In certain aspects the ideals of CoPUS was self-serving in that the intended outcome of interventions for an enhanced public-science relationship ensured a more positive view of scientific activities. Moreover, what CoPUS achieved was a mobilisation of the scientific workforce toward a more public-focused communication and knowledge dissemination approach.

The major criticism of this research framework is that, like its predecessor, it imposes a deficit on the public. Under the public understanding of science framework the deficiency imposed on the public is not only related to knowledge, but also in relation to *positive attitudes* of the public toward science (Miller, 2001; Bauer, 2007). The proposed solution to this *deficit* is through enhanced communication of information to the public, as lack of information is seen as the driver of negative attitudes to science and, by increasing public access to information, the impact of this negativity can be mitigated. The key component for the science community here is the notion that a knowledgeable public would be more inclined to support scientific endeavours rather than hold biases and negative opinions relating to science initiatives and research (Miller, 2004). This approach has attracted some criticism as it automatically assumes that a public is deficient in positive attitudes and that there exists a desire to learn about science and technology issues, which is counter to much of the contemporary theories about learning and attitude development (Stocklmayer & Gilbert; 2002). Furthermore it is claimed that this research framework does not take into account the literature on attitude formation and impact of knowledge and resistance to attitudinal change (Eagly & Chaiken, 1993).

As with the scientific literacy framework, the *public understanding of science* research paradigm continues to engage the public with a single-direction flow of information, despite the enhanced focus on science communication (Bauer *et al*, 2007; du Plessis, 2011). This unidirectional flow of information perpetuates the scientific communities' relative position of power as the disseminators and moderators of knowledge flows toward the general public (Miller, 1991). Battrawi *et al* (2013) discusses the impact social media and the emergence of the Web 2.0[10] has had on changing the influence of these power relations. Through enhanced bidirectional information flows and greater collaboration with respect to direct information through web-based tools (websites, apps etc.) networks consisting of generally interested members of the public and public-focused researchers

10 Web 2.0 relates to the emergence of more interactive and collaborative web-based interactions, rather than the former static web pages of the early online experience.

work in collaborative virtual communities to enhance information sharing and learning. Their findings relay the success of case studies in viable scientific communication through web-based platforms, offering collaborative opportunities via social media interfaces. The penetration of these services and multi-platform accessibility options represent viable new research and communication channels as the *World Wide Web* continues to evolve. However, particularly in the developing world, internet access remains relatively low, despite slow recorded infrastructure growth.

Much debate has surrounded public understanding of science as a research framework, including deliberations regarding methodological protocol (survey research or qualitative research), whether this framework truly serves the public and whether public involvement is, in fact, a stimulating or a moderating influence on science - as seen in the case of genetically modified foods (GMO) foods and early stem cell research (Pardo &Calvo, 2002; Critchley & Turney, 2004; McCarthy, 2010). Despite these debates, the *public understanding of science* research framework lends itself to understanding the science–public relationship in clearer terms. As Einsiedel *et al* (2001) argue, public participation in science in the early phases of research, rather than just as an impact assessment, is increasingly valuable, though not without criticism and caution.

Building on the scientific literacy framework, the *public understanding of science* paradigm seeks to understand the public-science relationship with greater definition than before, through the inclusion of public *attitudes* and *interests* in science measures. The increased public participation, and ongoing debates can be seen as highly constructive, facilitating increased communication and information flows between the public and the scientific community (Locke, 2002). What is clear from numerous research reports is that the general public has a declining interest in science and technology activities, despite increasing factual knowledge and access to information (Pouris, 2001/2006; Japan Science Report, 2001; India Science Report, 2005; Eurobarometer, 2010; NSF, 2010). This may be due to a trend of *information fatigue* where the increased availability and access to information has the opposite impact on interest in the subject matter (Darzentas *et al*, 2007). Despite the concern about the *public understanding of science* research paradigm with regard to issues relating to its incompatibility with contemporary theories about learning, outside of the education agenda and within the measurement domain there remains definite value for the research community under this research framework for ongoing study of the public-science relationship (Stocklmayer and Gilbert, 2002).

2.2.3 SCIENCE and SOCIETY

The European *BSE*[11]or 'mad cow disease' crisis, which started in the mid-1980s, and the public panic that ensued, saw an awakening within the scientific community, which began to take many of the critiques of the preceding two research paradigms into account (Jasanoff, 1997). The lack of effective public communication during the *BSE* crisis resulted in information being misinterpreted, leading to a sense of panic among consumers and hastening a European Union ban on British beef exports in 1996 (Stastny, 2005). Similarly the early discussions around GMO foods and stem cell research altered the public-science-policy edifice as much nuclear research was altered after Hiroshima in the late 1940s and early 1950s. While the interest in scientific literacy and public understanding of science didn't diminish, in the late 1990s a new research paradigm dawned, one that realised the direct value and importance of the public-science relationship and did not view the public simply as incidental to the scientific enterprise (Pardo &Calvo, 2002).

Following the critiques of the preceding two approaches, the 1990s ushered in changes to the study of the public understanding of science. This awakening within the scientific community reframed scientific advancement as more of a dialogue with the public. This saw the emergence of a more 'contextual approach' to the technological and research work of scientists, wherein knowledge flows were to become bi-directional and, in addition to the scientific enterprises' monopoly of scientific fact, the value of public opinion, local knowledge and social realities were increasingly being included to direct and promote scientific work (Miller, 2001). By the late 1990s, survey results emerging from the numerous studies within the *scientific literacy* and *public understanding of science* paradigms in the UK and elsewhere had revealed high general levels of interest in science. These surveys however indicated low levels of general public understanding of scientific developments and scientific fact (Burns, *et al*; 2003). Within this climate of low measured scientific illiteracy, Sturgis and Allum note the appearance of a rising 'public scepticism about the benefits of science' as well as an increase in negative attitudes in relation to technological advancements (Sturgis & Allum, 2004).

In 2000, the British House of Lords Special Committee on Science and Technology published a report entitled *Science and Society*, declaring a 'crisis of public confidence in science' (House of Lords report, 2000). The report highlights the obvious reality that science is a socially constructed enterprise that operates within a social context but that had in some respects come to be seen as insulated from the broader public (Bauer *et al,* 2007; Miller, 1998). Conducting scientific activity within a space devoid of social considerations and influences had, within the British context, invited

[11] *Bovine Spongiform Encephalopathy* (BSE), commonly known as Mad Cow Disease

a degree of public 'hostility' toward science (House of Lords report, 2000). The challenge faced by the research community, and highlighted in the *Science and Society* report was revised to include the understanding that public attitudes are informed by a variety of values, and the inclusion of this into research and policy was to be the critical task of the paradigm in order to increase public support for the enterprise. Sturgis and Allum (2004) note further evidence of public unease in relation to the real and potential risks associated with scientific advancements, from the concern related to DDT use in the 1960s to more contemporary public concerns, particularly in the United Kingdom. The impact of public opinion, particularly in relation to risk assessment of scientific work, had been highlighted as a powerful tool to swing the direction and progress of research (Miller *et al*; 1997 cited in Sturgis and Allum, 2004). The realisation of the enormous influence the public had on the direction and funding of (particularly public-financed) scientific work was highlighted by Lord Sainsbury, lead author of the House of Lords report, when he claimed 'the demise of the deficit model, instead calling for an increase in public-science communication under what he termed the *3 D's – Dialogue*, *Discussion* and *Debate* (Miller, 2001).

The idea of a public *deficit* attributed by the *scientific literacy* and *public understanding of science* frameworks has been reversed in the *Science and Society* paradigm (Bauer *et al*, 2007). Within this new framework it is not only scientific literacy, attitudes and interest that impact on the public-science relationship, but also the social context in which the public is located as well as the social, cultural and political influences that impact on the manner in which citizens interact with the world and the interpretation of information received. Bauer *et al* (2000) notes that the deficit within the Science and Society framework, is not attributed to *public knowledge* or *public attitudes,* but rather to the *deficit of public engagement* on the part of scientific actors and institutions that protract the belief of a public deficit on those fronts (Bauer, Petkova & Boyadjieva, 2000). *Science and Society* holds that the manner in which the public is perceived by the scientific community, and the various deficits imposed upon them, contribute to the communications approach employed, which discounts the impact of political, social and cultural influences on public perceptions of science. Furthermore, the attitudes and perceptions within the scientific community are highlighted, illustrating the misconceptions that perpetuated this perceived public deficit notion under the public understanding of science and scientific literacy paradigms (Reddy *et al*, 2009). Thus the public deficit notion was now reframed to include a deficit of positive attitudes and meaningful public interaction by scientists themselves toward the public's perceptions of science (Bauer *et al*, 2007).

The heterogeneity of the public is more fully appreciated when the multiple segments of society are acknowledged and the variability of communication approaches that would need to be mobilised under this approach are brought to the fore. The mobilisation of the scientific community toward a more public-centred approach was now popularised under this paradigm (Bauer, 2009). This feeds into public science policy and its subsequent impacts on public perception and apparent limitations on public participation in science (Felt & Fochler, 2008). The reframing of science as a product of social enquiry, technological and ideological accomplishment and human cultural heritage enveloped within the various societal and cultural milieus highlights the central concern of contextualisation within this research paradigm (Mansur, 2009). The traditional view of delineated public science interaction areas had been one of skewed power and authority relations. Within this understanding, scientists and researchers, as practitioners and custodians of science, had been perceived as being at the top of the knowledge pyramid, sharing ad-hoc information with a less-knowledgeable public. This view discounted the influence public and civic institutions had on the direction and evolution of the scientific enterprise and was seen to generate negative public opinion, which led to an essential lack of trust between the public and scientists that had to be corrected through public involvement and consultation (Stilgoe, *et al*, 2005 cited in Bauer *et al*, 2007).

The proposed 'new approach' highlighted in the House of Lords report under the *science and society* framework calls for the earlier inclusion of public participation in scientific endeavours toward resolving the '*crisis of trust*' that had emerged between the public and the scientific community (House of Lords Report, 2000; Miller, 2001; Bauer *et al*, 2007). The 'crisis' referred to was seen as a two-directional one where on the one hand the abovementioned lack of public trust in the scientific enterprise, and on the other the mistrust of the public by the scientific community on the grounds that due to low knowledge and an apparent lack in positive attitudes, public involvement in science may be counterproductive[12]. The focus of attention then is in relation to the deficit of technical experts who are publically accessible to more effectively interact with public groups and therefore foster a more secure connection between the public and the work of the scientific community. The report recommended many ways in which the public could be brought earlier into the consultation process with the research community - including public talks, citizen juries, review mechanisms, science centres and public communication training for scientists - toward bridging the gap between the two communities and rebuilding public trust in science (House of Lords, 2000). As a result, the perceived mistrust between the public and scientific community could be addressed through early inclusion of public input. Furthermore this addresses the lack in bi-directionality of information flows between science and the public at an early stage, rather than having a one dimensional flow of information toward the public on a post-hoc basis (Raza, 2002).

12 Some have argued that because of the "deficit" approach employed by preceding measures of *scientific literacy* and *public understanding of science* (attitudes and beliefs) frameworks, the study of the public is in itself tainted with bias toward the public from within the research community as a result of these earlier measures (see Bauer *et al*, 2009).

To achieve this, Rose (1999) argues that a 'mediator' act between the scientific community, policy makers and the public in order to facilitate information exchange, education and communication. These mediators [sometimes called *angels*] (Bauer *et al*, 2007), are tasked with rebuilding trust - both public trust towards scientific disciplines and vice versa. These often take the form of pressure groups, NGOs or politicians who serve the needs of both parties, toward enhancing interaction and greater understanding across the board. However, the House of Lords Report (2000) also notes that various approaches other than these mediators may play this role, including public opinion hearings, public conferences, national debates or citizen juries. These activities extend beyond just research projects and research outputs, but also include issues related to research policy, communication and national scientific productivity profiles as important points of influence in the science-public interaction space. Within this milieu, the media also has an enhanced role as communicators of scientific advances with the aim of promoting access to information, awareness, interest and positive attitudes toward science and technology-related areas (Rose, 1999). In South Africa, the media, with respect to public communication of science, has been shown to contribute a disproportionate share of editorial space to science-focused articles in media reporting (Van Rooyen, 2004; Claasen 2009, 2010). This is of particular relevance to the ongoing advancement of the South African science and technology system, in a country of many languages, cultures, beliefs and access to educational opportunities (see chapter 1.2). The importance of cultural relativity and indigenous knowledge systems extends into the science and society research framework as it decentralises the attention from "formal" scientific activities to include more informal or everyday scientific activities (Wynne, 1992; Miller, 1998; Raza *et* al, 2002; Du Plessis, 2011). Ziman and Wayne (cited in Miller, 1998) propose the notion that scientific meaning as a basis for a public understanding of science, is socially negotiated and the presumption that formal science supersedes 'local and informal knowledge' only promotes a deficit attribution. The Science and Society approach empowers the public to become active contributors to the scientific discipline, thereby enhancing their educational, employment and participatory prospects within a system that rewards the highly-skilled. Gauchat (2010), however, notes the risks associated with this approach as it could create an overemphasis on certain aspects within research, yet agrees with Wynne, Raza *et al* and Du Plessis in relation to the importance on local knowledge within the scientific domain.

The shift in research approaches and deficit attribution under the *science and society* paradigm does not however mean that there is no public knowledge or attitude deficit. What it does, however, is reframe the responsibility toward addressing that deficit to the scientific community (Miller, 2001, Raza *et al*, 2002). The case for literacy and the creation of positive attitudes remains a concern, yet the call has evolved toward a more interactive space wherein shared learning can be used to overcome these perceived obstacles. The recent increase in interest in scientific media across various platforms, from journal publications to social media platforms and blogs by both scientists and non-scientists has offered a new avenue to share ideas and information on scientific work for both the scientific community and the general public (Blik & Goldstein, 2013). While this does not always have the intended reach due to issues related to access and technical skill, particularly in the developing world context, it does present an important technological evolution that may in the longer term aid the scientific literacy agenda beyond the measurement domain.

This evolution of the study of public understandings of science has been described by Fuller (2000) as a 'new deal with society', bringing together both sides of the public-science chasm toward a better working relationship. This improved public involvement and upstream information-sharing approach, rather than the one-dimensional information filtering provides the space for empowerment of both parties while ensuring effective and accurate information sharing. Within the *science and society* framework, research and intervention are often blurred, leading to little agreement on how to accurately apply measurement techniques under this framework (Bauer, *et al*, 2007). Despite the notable conceptual alterations from *scientific literacy* and the advantage of cultural sensitivity it exhibits over the *public understanding of science* paradigm as a research framework, measurement for the purposes of developing indicators remains an ongoing challenge (Reddy *et al*, 2007). Bauer *et al* note, however, that the contemporary approach to evaluating the 3 D's approach of public consultation reprises the earlier methodology of public understanding of science and scientific literacy with respect to its application of survey protocol, albeit in relation to public participatory activities (Bauer *et al*; 2009).

2.3 THE EVOLUTION OF MEANING: DEFINITIONS AND THE PUBLIC UNDERSTANDING OF SCIENCE[13]

The three frameworks discussed above and the historical context underpinning their development, evolution and impact on the study of the public understanding of science all converge when trying to assimilate a sense of meaning toward the development of an actionable definition for research application. Within the context of this study the view has been adopted that despite the three (3) research paradigms being conceptually dissimilar, when distilled to their essential elements, they present a far richer and more complementary view toward effective research in this domain (Bauer *et al*, 2007). The underlying interest within each paradigm relates to levels of public knowledge, public attitudes and public participation and, when integrated, represents a viable model for the

[13] Here the terms "public understanding of science" and "scientific literacy" do not refer to the specific research frameworks described above, with their varying focus on knowledge or attitude acquisition, but are instead used to describe the body of knowledge within this research domain, as a means to simplify and forward the discussion of this concept within this paper, and may be used interchangeably or simultaneously. Where otherwise intended, this will be denoted.

construction of a scientific knowledge ecosystem within which the individual, as the basic unit of the 'general public' exists. Despite the understanding that an absolute measurement of the public understanding of science is both complex and particularly challenging to fully achieve, epistemological work continually informs evolutions in research approaches (Wenning, 2011).

The traditional approach to studies of this nature has located itself within the boundaries of one of the abovementioned research paradigms, each exhibiting the complementary and critical response attributed to the specific framework within the academic literature. Much of this critique is related to the varied interpretations of what it means to be 'scientifically literate' and what the study of the public understanding of science' in reality should entail. However, as previously noted, definitional aspects have played a crucial role in developing ever-expanding notions of the nature of this at times controversial concept. Laugksch (1996) likens the concept of *scientific literacy* to terms such as *liberty, justice and happiness (p. 23)*; highlighting their simple, socially understood properties, and also similarly present highly complex definitional characteristics. Due to the multi and inter-disciplinary nature of the study of scientific literacy (or the public understanding of science), research from diverse theoretical branches of academia have made significant contributions to the modern conceptions within this domain and as a result has confounded cross-interpretability between the various interest groups actively involved within this domain. Laugksch has proposed five (5) factors that influence the various interpretations of the concept, namely: interest groups, definitional properties, the nature of the concept, the benefits of scientific literacy and measurement approaches. These five factors each bring multiple facets of perspective to the discussion on scientific literacy and within that, provide varying interpretations of what is implied in its study (Laugksch, 1996). The review of definitions below adopts the five elements within Laugksch's conceptual overview. It further asserts that the most salient of these facets is located within the interest groups promoting the study of scientific literacy. This departure from Laugksch is related to the notion that the remaining four factors within Laugksch's conceptual model are all dependent and resultant from the general approach and perspective of the interest group concerned. Consequently, the influence of the interest group promotes a particular notion of the public understanding of science, the nature of the concept, its benefits, measurement approaches and definitional properties and is all then directed within the particular world-view of that interest group. The review below will therefore focus primarily on the impact of interest groups in focusing the study and definitional properties of the varying notions of scientific literacy and the public understanding of science.

2.3.1 INTEREST GROUPS

Interest groups represent a variety of ideological positions and may differ significantly on a common point of interest. Jeffery Berry defines an interest group as 'an organised body of individuals who share some goals and who try to influence public policy' (Hays, 2001). These may have an alignment to business, labour unions, public health issues or educational initiatives (Chari et al, 2010). Scientific literacy has commonly operated within the educational agenda, and has been positioned as important for ongoing and effective educational attainment (deBoer, 2000). However, despite the shared educational importance within scientific literacy, Laugksch (1996) identifies four (4) main interest groups operating within the research community that influence the interpretation of public understanding of science and scientific literacy research beyond the educational sphere.

The first of these is the science education community, who are primarily concerned with the goals of science education, educational reform, quality of education and assessment of educational outcomes with a primary focus on the formal educational setting, assessment and curriculum reform. Laugksch then highlights the social scientists and researchers as a second interest group actively involved in this research area. The main concern for this interest group is in understanding public support for science, the attitudes associated with it and the sources of scientific information within a given population. The focus of this interest group is in relation to measurement and indicator development, and is primarily concerned with the school leaving, post-schooling and adult members of the population. The third interest group is the sociologists of science, who are principally focused on the authority of information, how information is disseminated and received by the general adult population and the impact this has on the public support for science. Lastly, Laugksch (1996) identifies the informal science communicators' interest group, usually working within the journalistic or museum and auxiliary science educational environments. The key focus for these individuals centres on the effective communication of science and the public interaction with scientific information among all age and population groups.

The core focus and community of concern for each of these interest groups directly influences the operationalisation of key aspects within the study of the public understanding of science. These may directly influence the understanding of the nature of the concept, proposed benefits of scientific literacy and measurement approaches within Laugksch's conceptual view of scientific literacy. It further is directed toward specific public and policy action areas as a result of the particular world-view adopted by researchers advocating public understanding of science and scientific literacy research (see Lewenstein, 1992). These interest groups and the researchers that emerge from within them, influence the operationalisation of the concept of scientific literacy and the public understanding of science through the formulation and adoption of definitional characteristics suited to the ideals of the various research traditions informing those groups.

2.3.2 Definitional characteristics

As a basic foundation of the measurement of the public understanding of science, the precise definition of scientific literacy has been the objective of many researchers since the 19th century (Millar, 2007; Osborne, 2007; Hodson, 2008; Wenning & Wenning-Vieyra, 2009; McGregor & Kearton, 2010). The above discussion on interest groups outlines the discussion on the definitional characteristics of scientific literacy through the influence of interest groups and the many researchers that have attempted a mutually agreeable definition since at least the mid-20th century (e.g. Snow, 1969; Shen, 1975; Miller, 1983; Hazen & Trefil, 1990; Burns et al, 2003; Holbrook, 2009). Layton *et* al (1994), in their publication on behalf of UNESCO, document a list of scholarship dedicated to the area of scientific literacy, highlighting one hundred and ninety five (195) definitions of scientific and technological literacy , to varying degrees of agreement.

The works of Laugksch (1996), Zuzovsky (1997), DeBoer (2000), Roberts (2007) and Hodson (2009) all offer comprehensive reviews of the evolution of the definitions of scientific literacy and the public understanding of science. Whilst many of the earlier debates of the 19^{th} and 20^{th} century related to the discussions around the ‘two cultures of science’ (see Huxley, 1880; Arnold, 1882- cited in Miller 1983; Snow, 1959 and Leavis, 1962), the latter part of the 20^{th} century altered the discussion toward a greater focus on the *contextualisation of science* and its application to lived human experience (Feinstein, 2010).

Despite the ongoing definitional conversations and discussions, what early advocates like Huxley (1880), Dewey (1934) and Davis (1935) call the concept of ‘scientific attitudes’ or ‘habits of the mind’ remain central to the study of the *public understanding of science* (Zuzovsky, 1997). These concepts relate specifically to the notion that open-mindedness, fact-based intellectual integrity and the interest in testing opinions and beliefs are important for the advancement of the individual and society as a whole (Anelli, 2011). While acknowledging the foundational work of the early contributors to the field, it is clear that the watershed period for the epistemological advancement in this discipline dawned post-World War 2, with the many scientific and technological advancements that were made then, as discussed earlier.

In 1958, Paul Hurd, a member of the educational interest group, proposed that the goal of formal science education should be the development of a ‘scientific literacy’ in students. The term, under Hurd, implied the development of an understanding of science and its implications for the development of the individual as a socially, politically and economically active citizen (Hurd, 1958). Much of this was related to the post-Sputnik socio-political period in the USA discussed previously, as Hurd emphatically states the importance of a scientific literacy for the continued special progress and security of the American people (Hurd, 1958 – p.52). Following Hurd, a number of scientific literacy advocates emerged from within the education agenda during the 1960s, advocating curriculum reform toward a scientific literacy focus - what Laugksch calls 'the period of legitimation' (Laugksch, 1996; Baybee, 1997). Many of these advocates rallied behind Hurd's (1963) definition of scientific literacy, which included the knowledge of scientific concepts, an understanding of the relationship between scientific concepts and an awareness of the limitations of science. Shamos, in this same period, highlighted a form of social scientific literacy, in which the outcome of scientific education is a scientific literacy where an individual feels comfortable talking with others about science in non-technical terms (Wenning & Wenning-Vieyra, 2009, p.28). Koelsche (1965) raised yet another definition of scientific literacy, seeing it as an accumulation of knowledge and skills required to understand science as presented by the media (Hazen &Trefil, 1991; Goolam, 2001). In his research, Koelsche proposed one hundred and seventy-five (175) scientific principles and six hundred and ninety-three (693) scientific words that regularly appeared in the media and should form the foundations of scientific teaching in the educational curriculum in order to foster a greater degree of scientific literacy – under his definition (Koelsche, 1965 - cited Wenning & Wenning-Vieyra, 2009). Pella *et al* (1966) performed an analysis, in studying 100 journal articles identifying six (6) characteristics of a scientifically literate person (Laugksch, 1996). These characteristics include an understanding of a) the interactions between science and society b) the ethics of science c) the nature of science d) the basic concepts of science e) the relationship between science and the humanities, and f) the difference between science and technology (Layton *et al*, 1994; Goolam, 2001). Showalter (1974) continued the work of Pella *et al* (1966) and defined scientific literacy as having seven (7) dimensions, and providing a specified list indicating a continuum of characteristics developed within the scientifically literate person that was not seen in the contemporary definitions of the time (Wenning & Wenning-Vieyra, 2009).

The role of the demand for access to science-focused knowledge since the late 1950s in shaping and focusing the democratic development of public policy in relation to scientific developments and funding was explored by Benjamin Shen in 1975 (Zuzovsky, 1997). Shen proposed three (3) categories of scientific literacy: *cultural scientific literacy, practical scientific literacy* and *civic scientific literacy* in describing a need to teach science in a real world context (Wenning & Wenning-Vieyra, 2009). *Cultural scientific literacy* included the appreciation of science as a major human achievement, *practical scientific literacy* included an understanding of the basic concepts in, and applications of, science in order to improve everyday living standards, while the third category, *civic scientific literacy,* included the knowledge and understanding required of a democratically active citizen able to engage in contemporary scientific debates (Anelli, 2011). Laugksch (1996) notes that these categories of scientific literacy are not mutually exclusive and an individual may have varying degrees of each kind of literacy and further denotes the importance of these in relation to democratic development, particularly in the developing world context. Similarly, Hazen & Trefil (1991) and Miller (1983, 1998) also explore civic scientific literacy and continued from the work of Shen, claiming civic scientific literacy as critical for citizens in modern society (Anelli, 2011). Branscomb (1981 – cited in Laugksch, 2000) defined scientific literacy to include the ability to '*read, write and understand systematised human knowledge*' (p.77). Like Shen, in her analysis, Branscomb (1981) identified eight (8) classes of scientific literacy important to effective human engagement with science and society, and related to a particular context of human engagement (see Laugksch, 2000, p. 77). The classes of scientific literacy proposed by Branscomb operated within the science policy paradigm, offering multidimensional approaches to the study of scientific literacy and the public understanding of science applicable to various practical application contexts (Goolam, 2001).

This idea of functional literacy is further shared by Dewey (1934) and Miller (1983) in the development of the three (3) consecutive dimensions of scientific literacy that have become the basis of contemporary measurement indices (Bauer 2007, 2009; DeBoer, 2000). Miller's multi-dimensional approach to measurement focused on three dimensions of scientific literacy, namely a) an understanding of the methods of science, b) an understanding of the facts and concepts of science and c) an appreciation of the impact of science on society (Miller, 1983; p. 33-35). Miller's definition proposes an outcome whereby, for a citizen to be scientifically literate, they would essentially need to possess the skills to read, write and engage meaningfully in daily activities and interact with scientific material in the media or vocational settings (Miller, 1983, 1998, 2004). In Miller's definition, scientific literacy became a threshold measure, relative to the standard set by knowledgeable members of society, and thus may vary depending on the context of operationalisation (Anelli, 2011). Miller contends that in a democratic society, the level of scientific literacy in the population has important implications for the democratic, economic and decision-making capabilities of individuals, who constitute the basic unit of the 'public'. Many of these ideas have been incorporated into Arons (1983) *12 attributes of scientific literacy and its importance in application to everyday life* and Baarah & Volk (1994) on the influence and application of science (cited in Goolam, 2001).

Hazen and Trefil (2009) defined scientific literacy or the public understanding of science as "the knowledge you need in order to understand public issues". This refers to the knowledge assumed to be known by the audience that need not be explained in order to fully grasp the topic under discussion. Laugksch (1996) likens this to the concept as seen by Hirsch (1987 – in Laugksch, 1996) as the de facto *sine qua non* of social interaction, and of particular importance to science communication. To Hazen & Trefil, as it was with Dewey, Miller and Arons, scientific literacy implied grounding in the fundamentals of science in order to fully participate as a citizen in a democracy. Hazen and Trefil (2009) note in their introductory chapter that, 'one needs to know some facts, be familiar with some general concepts, to know a little about how science works and how it comes to its conclusions, and to know a little about scientists as people' (page XXI). They propose 18 key concepts, which they call *great ideas and* believe 'frame virtually all scientific advancements', that all citizens need to be familiar with in order to be scientifically literate (Hazen and Trefil, 2009).

Gabel (1976) differed from the abovementioned scholars in that he proposed a two-dimensional model of scientific literacy (Liu, 2009). The first dimension dealt with the types of content involved in scientific literacy, such as the facts, process and methods of science. The second dimension involves the types of reasoning involved in assimilating scientific knowledge and the manner in which this impacts the varying forms and levels of scientific literacy. Likewise, Shamos (1995), most commonly associated with the opposing the dominant views on scientific literacy in the modern educational interest group, identifies three (3) types of scientific literacy: cultural scientific literacy, functional scientific literacy and true scientific literacy (Shamos, 1995; Liu, 2009). Under Shamos, cultural scientific literacy requires that the individual has a basic familiarity with scientific concepts and terms, while functional scientific literacy demands that, in addition to the individual being familiar with the concepts, they are also able to apply them meaningfully. The distinguishing factor between these two typologies is that where cultural scientific literacy is passive, functional scientific literacy is active and transforms the individual from a mere recipient of information toward interrogating and communicating scientific information (Laugksch, 1996). The third level, under Shamos (1995), is true scientific literacy, which includes an understanding of the overall scientific enterprise as well as the major theories and contributions to science advancement. Shamos adopts the view that these levels of scientific literacy are evolutionary, and as an individual continues to engage ever-more closely with the scientific discipline, the scientific mind-set evolves. While it is noted that the first two levels are fairly common in contemporary society, Shamos does acknowledge that the third level of scientific literacy is exceedingly difficult to attain due to increasing specialisation within the varying knowledge areas in the scientific discipline (Shamos, 1995; Laugksch, 1996; Liu, 2009).

Baybee (1997) similarly identifies a continuum of five types of scientific literacy, from *nominal, functional, conceptual, procedural* and *multi-dimensional* scientific literacy. These five types of scientific literacy share much with the model offered by Shamos (1995), but differs in that multi-dimensional scientific literacy is not as stringent as Shamos' *true scientific literacy* and is therefore more attainable by a greater portion of the population. More recently, Norris & Phillips (2003) proposed that scientific literacy or the public understanding of science would involve varying degrees of influence from a list of eleven (11) components they identified as most relevant. These are: content knowledge, understanding of the applications of science, the nature of science, the independence of science, scientific habits of mind, applying scientific processes to problem solving, participation in scientific issues, recognising sciences' relation to culture, appreciating the outputs of science, knowledge of the risks and benefits of science and the ability to think critically about science. Feinstein (2011) continues from the concept of *functional scientific literacy* introduced by Miller in 1996, by proposing *useful scientific literacy* in arguing the meaningful social and personal application of science to daily living.

The definitions of scientific literacy and the public understanding of science have evolved over time and as a result of the various researchers and interest groups seeking to find a common point of departure for measurement. Hurd (1998) notes that the contemporary trend toward hybridisation across scientific investigations, including the public understanding of science, adds to the ongoing dilemma in arriving at a point of common definition. Lewenstein (1992) notes that the influence of post-World War 2 developments in the United States, in particular, not only accelerated the amount of science information directed toward the general public, but also highlights the increasing public appetite for science following the many wartime technological developments that held promise for increased quality of life. Despite the lack of agreement in definition, Lewenstein notes the overall agreement among researchers of the intent of the scientific literacy and public understanding of science movements as one embracing the ideal of developing a greater public appreciation, interest and awareness of the benefits, developments and value science offers society (Lewenstein, 1992). The respected historian of science Michael Shortland notes, '…to become scientifically literate is to become an active and effective citizen' (cited in Sapp, 1992). What has emerged in the above analysis of the changing meanings of 'scientific literacy' and the 'public understanding of science' is that the initial work of Dewey (1934), Davis (1935) and later Shen (1975) and Miller (1983) have given rise to common definitional threads that are visible in the very essence of the work that has followed them. Holbrook and Rannikmae (2009) note this and highlight two major streams in public understanding of science research with regard to definitions: the first stream advocating a pivotal role for knowledge and attitudes, and the alternative stream highlighting societal usefulness in defining scientific literacy.

What is most important in the above review of the various definitions of the public understanding of science is the evolutionary nature of the concept, and the changes the definitions undergo as science evolves and changes its relevance to society. These scientific and technological advances provide a framework within society from which to constantly review and revise the definitions of scientific literacy and the public understanding of science (Hurd, 1998). The common characteristics presented in the table below represent viable dimensions as a point of departure from which to embark toward developing a definition for measurement in the current study.

Period	Main Contributor	Proposed working definition
1930	Dewey	*The main outcome of general education*
1952	Conant	*A broad social understanding of science for practical application*
1958	Hurd	*An understanding of science and its application such that the outcome results in social benefit (economic, political and personal)*
1960's	Various	*Used as a major educational aim toward bolstering the educational agenda*
1960's	Shamos	*Having a practical understanding of science such that daily applicability becomes a reality*
1963	Hurd	*Knowledge of key scientific concepts and being apple to apply them in a socially coherent manner*
1963	Koelsche	*The knowledge and skill of science required to engage with subject matter as reported in popular media*
1966	Pella, O'Hearn and Gale	*The interrelations between science and society and the relative impacts*
1971	NSTA	*The ability to use scientific concepts in everyday life and social interactions, as well as an understanding of technology*
1970's	Shen	*Practical scientific literacy valuable to daily lived situations*
1970's	Shen	*Civic scientific literacy- knowledge that enables active civic participation and democratically supports processes in society and in public policy issues*
1981	Branscomb	*The ability to read, write and understand systematised scientific knowledge*
1983	Arons	*Correctly being able to apply scientific knowledge toward daily problem solving in personal, professional and civic settings*
1983	Miller	*Three dimensions of scientific literacy, namely a) an understanding of the methods of science, b) an understanding of the facts and concepts of science and c) an appreciation of the impact of science on society*
1987	Hirsch	*Cultural literacy entails a grasp of the contribution science makes to the cultural stock of humanity*

1986	Scribner	*Knowledge that is simultaneously adaptive, socially empowering and self-enhancing*
1990	Hazen and Trefil	*Should empower people to develop meaningful context for science news as reported.*
1992	Lewenstein	*Developing a greater public appreciation, interest and awareness of the benefits, developments and value science offers society*
1994	Baarah and Volk	*An understanding of how science, technology and society influence each other*
1995	Shamos	*(a) cultural science literacy: a grasp of certain background information underlying basic communication,* *(b) functional science literacy: not only know the science terms, but also to be able to converse, read, and write coherently using these terms in non-technical contexts, and* *(c) true science literacy: understand the overall scientific enterprise and the major conceptual schemes of science, in addition to specific elements of scientific investigation*
1995	Fensham	*Conceptual learning contextualised in real world situations and reasoning*
1996	Eisenhart, Finkel and Marion	*Multidimensionality of scientific literacy - an understanding of science within a social system, with many dimensions impacting the individual and society*
1997	Beybee	*Functional literacy, conceptual literacy and procedural literacy*
1999	Jenkins	*Citizen Science - reflexive approach to understanding science, taking public concerns, interests and activities into account*
2004	Miller	*Public would essentially need to possess the skills to read, write and engage meaningfully in daily activities and interaction with scientific material in the media or vocational settings*
2009	Hazen and Trefil	*The knowledge needed in order to understand public issues*
2011	Feinstein	Functional scientific literacy (introduced by Miller) – Useful Scientific Literacy in arguing the meaningful social and personal application of science to daily living.

Table 2.2: Evolution of Meaning: Public Understanding of Science (Adapted and expanded from Goolam, 2001)

Chapter Three

Literature Review: Global Empirical Evidence

The whole premise of democracy is that it is safe to leave important questions to the court of public opinion—but is it safe to leave them to the court of public ignorance?

Isaac Asimov (1989)

3. REVIEW OF EMPIRICAL STUDIES ON THE PUBLIC UNDERSTANDING OF SCIENCE

As noted in Chapter Two, empirical studies of *scientific literacy* and the *public understanding of science* have been conducted since at least the mid-1950s. Many of these have been replicated in a number of settings around the world, giving rise to ongoing debate about cultural sensitivity and the cross-national applicability of measures within this domain[14]. Whilst numerous authors have commented on the applicability and value of public understanding of science research for a variety of developmental, educational and democratic ideals, the socio-cultural setting and design of the vast majority of studies conducted do tend to draw on the social context wherein the research is located (see Laugksch, 1996; Raza, Singh & Dutt, 2002; Shukla & Bauer, 2009).

Although many scholars have replicated internationally benchmarked studies by using similar measurement instruments and approaches, content, subject selection and test construction have differed as a result of the studies' geographic location. Furthermore, the notion of relative development and its influence on education and other socio-demographic factors have further influenced the directed aims of *public understanding of science* research across varying geo-social landscapes. For this reason, the review below will cover the most influential studies of *public understanding of science* conducted in both *developing* and *developed* world settings. While some have argued that the distinctions between these country-labels require revision (see Hasan, 2013), these broad categories do offer some structure toward categorising research within this domain from distinct geographic regions (United Nations Statistical Services Branch, 2006).

The below review offers some insights into scientific literacy and public understanding of science research from diverse global regions; it is by no means exhaustive nor does it cover the entire body of research within this domain. What is however achieved is a broad impression of the state and direction of global research and the approaches adopted within the selected studies. While some studies relate to national indicators of *scientific literacy* and *public understanding of science* in terms of general science focus areas, others have concentrated on issues relating to biotechnology, climate change, nuclear power or similar specific subject matter. The review below highlights large and

[14] These issues will be addressed in this chapter under the discussions around instrument development

smaller studies from the USA, Canada, the United Kingdom, Germany, Japan and Australia under a broad category of more economically developed nations, while studies from China, Malaysia, India, and South Africa represent studies emanating from a diffuse cohort of newly industrialised or developing countries.

3.1 EMPIRICAL STUDIES FROM DEVELOPED COUNTRIES

3.1.1 United States of America - NSF: Science and Engineering Indicators (SEI)

The *National Science Foundation (NSF) Biennial Science and Engineering Indicators (SEI* is considered the most well-known compendium of science and technology indicators. While the focus of this publication is on the full scope of the science and engineering enterprise in the United States of America, more recent editions have presented international data reflecting comparisons with comparable data from other geographic regions. The *SEI* presents a volume of science and technology indicators across eight (8) themes, providing an overview of the scope and environment of the science and engineering system of the USA (NSF, 2014). These themes include indicators for Mathematics & Science Education; Higher Education in Science & Engineering; Human Resources for Science & Engineering; Research & Development Indicators; Academic Research; Industry, Technology & the Global Marketplace, State Indicators as well as indicators for Public Understanding and Attitudes toward Science & Technology. Whilst it is important to understand the contents of the entire document in order to extract the most value out of its findings, this section will focus specifically on the chapter related to the *public understanding of science* outputs from the *NSF-SEI 2014*.

The *NSF Science and Engineering Indicators* publication uses multiple data sources and amalgamates data from varying studies toward producing the different themed chapters (NSF, 2014). The NSF study has included a module on the *public understanding of science* since 1979 (Reddy *et al*, 2009). This chapter was in the past composed from data sourced from a specialised NSF survey of between 1500 and 2100 adult individuals using telephonic interviews to access a nationally representative sample of United States citizens. The survey requested information on sources of public information about science, visits to science institutions, general attitudes toward science, animal research and government science spending as well as information on science and mathematics education (NSF, 2014). However, since 2006, the NSF has used data for this module using the *General Social Survey* conducted by the National Opinion Research Centre at the University of Chicago. The GSS is a multi-module sociological survey accessing data on a core set of behavioural and attitudinal questions as well as special interest topics from a nationally representative sample of adults across the USA (NORC, 2013). Despite the change in data source, the same information points are accessed under the GSS, using face-to-face interviews (supplemented by telephone interviews) however, with a sample of between 1800 and 2200 respondents. The most recent release of the *NSF Science and Engineering Indicators*: *public understanding of science* data was in 2014, reflecting data from the 2012 GSS survey.

The chapter on *public understanding of science* is divided into four (4) main sections, reflecting the design and wording of the survey questionnaire. Under these are included assessments of public *interest, information sources, involvement in science; public knowledge about science, public attitudes about science (in general,* and *public attitudes about specific science-related issues*. All sections were assessed by providing the respondent with a series of question and answer choices.

Public interest in science was measured by presenting respondents with a list of topical news items related to science issues and respondents were asked to rate their level of interest on a 4-point scale ranging from *very interested* to *not at all interested*, with the fourth category being a *don't know* option. The science issues presented included *new medical discoveries, schooling, economic, political, environmental and business issues, application of new technologies, military, space exploration and agricultural aspects of scientific advancement*. Information was also collected on major sources of science information along four (4) information streams: *television, internet, newspapers, other* (a *don't know* option was also included here). Also identified here was American involvement in informal scientific spaces such as science centres, museums and zoological and botanical gardens.

Public scientific knowledge was assessed by presenting respondents with a 9-question index of factual scientific knowledge and measuring answers to these questions through four (4) response categories. Examples of these questions from the 2014 data are: *the centre of the earth is very hot* or *electrons are smaller than atoms* and, in addition to the true or false response options, respondents could also indicate a *don't know* or *refusal* response. *Understanding scientific processes* as opposed to just measuring scientific facts was also measured using a series of questions requiring the understanding and application of three (3) scientific principles: probability, experimental design, and an understanding of what it means to study something scientifically (NSF, 2014). The results of these three question sets were calculated to derive the *components of understanding scientific inquiry* scale toward presenting a composite measure of *understanding scientific processes*. Also included under this section was a single question that aimed to measure respondents' ability to distinguish science from pseudoscience by asking if they believed astrology to be scientific in method and practice.

General attitudes toward science were measured using the *index of promise and reservation*, which employs questions assessing perceptions of *benefit* and *risk* associated with scientific advances in general. Promise and reservation indices generally include items that present results of scientific study as beneficial, items that present results of scientific study as equal in benefit and risk as well as items that present results of scientific study as presenting more risk than benefit. The number of items in the scale may vary; however these consistently include the above-mentioned attitudinal response options for respondents to choose from in an *index of promise and reservation*. In addition to measuring general attitudes toward science, influence of scientific experts, relevant scientific research fields, attitudes about scientific careers, confidence in scientists and government funding of scientific research were also assessed under this section. The study also presented findings in public attitudes to specific scientific issues including *environmental, climate change, nuclear power, genetically modified food, stem cell research*, as well other areas of scientific research.

The results are presented as trend data to indicate change over the biennial period, as well as historic data plots of previous editions of *SEI* data and, wherever possible, international comparisons are offered to further contextualise the results relative to other populations.

Assessment area	Specific measures	Examples of NSF – *SEI* 2014 findings
Information / Interest	• Information sources • Interest in science	• Americans are mostly interested in "new medical discoveries" • The internet is the main source of scientific information • Television remains the main source of news information
Public knowledge	• Factual knowledge • Scientific processes • Superstitious beliefs	• 65% correctly answered factual knowledge questions • Lower scores on *indicators of understanding scientific processes* • More Americans now believe astrology is scientific than in 1983
General attitudes	• Benefits & Risks • Influence of experts • Research fields • Scientific careers • Government funding	• Americans continue to value the benefits of science over risks • Government should continue to fund basic research • Scientific and medical researchers are held in high confidence • Americans rate applied research fields as more scientific • Fewer identified social science as being scientific
Specific attitudes	• Environmental • Climate change • Nuclear power • GMO foods • Stem cell research	• 37% of Americans expressed concern over environmental issues • 42% believe human activity has increased global warming • More Americans favour nuclear energy • 76% believe renewables could address America's energy needs • Americans are more concerned about GM animals than plants • 60% see stem cell research as 'morally acceptable' • Human cloning still remains a particular concern to many

Table 3.1: Abridged results - 2014 *Science & Engineering Indicators*: Public Understanding & Attitudes to Science

(Table structure adapted from Reddy *et al*; 2009, data updated to reflect 2014 NSF release)

All results are analysed and presented along a number of demographic factors measured in the NSF publications and provide further insight into the findings of this important publication. Table 3.1 above presents a highly abridged view of overall results of the *2014 science and engineering indicators: public understanding and attitudes to science* along the four (4) dimensions discussed above.

3.1.2 OECD – Canada: Programme for International Student Assessment (PISA)

Another large study of public understanding of science as well as related areas of mathematics and reading literacy is the project of the Organisation for Economic Co-operation and Development (OECD), called the *Programme for International Student Assessment* (PISA). The programme was initiated in 2000 and has since been conducted on a three-year cycle with its primary aim being to evaluate skills and knowledge in key areas of mathematics, reading and scientific literacy among 15-year-old learners (OECD, 2013). The OECD is a key international institution founded in 1961, and has thirty-four (34) member states and a number of non-member or observer states that partner with the OECD on matters pertaining to international cooperation, trade and developmental issues (Clark & Thomson, 2011).

The PISA project has been active since 2000 and, as part of its methodology, run surveys every three years, along one of the three subject areas of interest. The project has amassed a major database of information on learner literacy in mathematics, reading and scientific literacy and holds data on more than seventy (70) countries from both the developing and more developed economies participating in its work. The 2012 iteration of PISA focused on mathematics literacy and measured 510 000 learners from 65 countries. PISA compares well with other, similar, large international studies such as TIMSS (Trends in International Math and Science Study) and the Progress in International Reading Literacy Study (PIRLS), showing high positive correlations across measures in the different questionnaires (Wu, 2009). The PISA assessment is conducted in a number of different geographic and cultural settings and is thus not the identical test in every location, accounting for language, socio-cultural and educational variances between locations. The test construction is a combination of open-ended and multiple choice questions. Learners are required to apply the pertinent subject matter (math, reading or science literacy) to solve everyday problems presented in the questions. Raw scores from each participant country are scaled to allow meaningful comparison of cross-national data based on different question combinations (Stanat*et al*, 2009). PISA offers a unique advantage over other assessments as it does not rely on mastery of school curricula, which is vastly diverse in different geo-social locations. It focused on the extent to which learners would be able to cope with daily challenges post-formal schooling years (OECD, 2013).

PISA 2012 maintained a focus on mathematics literacy assessment among learners; however had also investigated reading and scientific literacy in the course of its data collection. The 2009 iteration of PISA had its focus on science literacy, and in the interests of obtaining a view of different empirical studies from varying locations, data from Canada was selected on which to focus the remainder of the discussion on PISA below. In 2012, 21 000 Canadian students from 900 schools participated in PISA, tests were administered during school hours in the second quarter of 2012.

The PISA assessment explores scientific literacy along three dimensions: a) an understanding of science concepts, b) an understating of the scientific process and c) the application of these in lived situations (OECD, 2009). Due to the fact that PISA focuses on one of the major domains of science literacy, mathematics literacy or reading skills in each 3-yearly iteration of the study, major and minor domains receive a slightly different attention depending on the focus within the specific survey cycle. In cycles that have a focus on science literacy, students' general attitudes toward science as well as their cognitive capabilities and application of scientific knowledge are assessed. In a cycle where science literacy is a minor focus, only questions relating to the testing of cognitive and application of scientific knowledge capabilities are assessed (OECD, 2006). As a basic question in the public understanding of science domain, PISA asks why it is important for citizens to be knowledgeable and capable in situations involving science and technology issues. The analysis of data from the groups of 15-year-old learners provides insight as to how this may impact them later in life as well as how to best educate for a changing world.

The assessment of *an understanding of science concepts* is achieved through asking a series of questions applying scientific concepts to human experiences under broad themes, including *science in life and health*; *science of the earth and the environment* and *science in technology*. The questions here focus more on the relevance of the concept for lived-experience and its relation to scientific areas as a means to test concept recognition within context rather than simple fact recalling capabilities (Knighton *et al,* 2010). The second assessment category focuses on *an understanding of scientific process*, and looks at the capabilities of learners to identify, interpret and act upon evidence presented within stimulus material preceding the question sets (OECD, 2006). In the 2006 PISA study, an example is used of a newspaper article describing how DNA evidence was used to identify a criminal (OECD, 2006). The questions that follow this stimulus material relate to its content as well as the application of the information so as to identify evidence and make inferences. The questions are carefully constructed to ensure that the learners would not require a pre-existing body of scientific knowledge to answer the questions, but instead focuses on the learners' ability to identify and follow a scientific argument when provided with the given evidence (Stats Canada, 2013). The last category in the public understanding of science assessment framework measures the learners' capabilities in recognising scientific aspects in an everyday context as well as the ability to apply these to the personal, social and global context (OECD, 2006).

Key to the development of the PISA scientific literacy assessment of 15-year-old learners is the interaction of scientific concepts, processes and application based on evidence toward fostering effective citizenship (Knighton *et al,* 2010). The Canadian results of the 2012 OECD/PISA study indicate that overall, Canada has performed above the OECD average in all three categories of the study. However, these results also indicate that, relative to previous iterations of the PISA study of the Canadian adolescent population over the last nine (9) years, there has been a decline of scores (Brochu et al, 2013). In terms of the scientific literacy measures, Canadian learners again performed above the OECD average, attaining a score of 525, 24 points higher than the OECD average of 501. In many OECD countries, males outperformed females in measures of scientific literacy; however, in Canada there was no significant variation between male and female scientific literacy scores. As with the overall performance among the Canadian participants, scores for scientific literacy do indicate a statistically significant decrease between the 2006, 2009 and 2012 iterations of PISA study (Brochu et al, 2013). During the same period the OECD average for science literacy scores remained relatively unchanged, though fluctuations in performance on science literacy elements for individual country scores were observed.

3.1.3 Europe – Multi-Country: Eurobarometer Special Module on Science and Technology

The European Commission was first established in 1951, with nine (9) member states (CVCE; 2012). Today the European Commission has twenty-eight (28) member states, with the inclusion of Croatia in 2013 (European Commission; 2013b). Since 1974, the European Commission has regularly conducted public opinion research toward the annual Eurobarometer *Survey* report. The Survey was developed to be a cross-national longitudinal study of the EU-27 nations, designed to measure public opinion and highlight trends on a variety of social and public issues in an annual survey of adults, 15 years and older. While the first Eurobarometer surveys focused on social issues related to the then current economic climate of the early 1970s, later iterations of the multi-national poll expanded its focus to include questions on democracy and governance, health, employment, education and many other thematic areas of interest (Reddy et al, 2009). In addition to the standard Eurobarometer survey, since 1990 the European Commission has also been conducting regular modules on special issues of interest, mostly on a biennial basis. In 1990 the first survey of *Europeans' Attitudes toward Science and Technology* was conducted, and it has since been repeated in each wave of the Eurobarometer (European Commission, 2013a). The most recent iteration of *the Attitudes toward*

Science and Technology module was published in 2013 and the results of this survey wave are discussed below.

The public understanding of science module in the Eurobarometer survey adopts the established dimensions of public understanding of science and scientific literacy research in identifying exploratory areas of its questionnaire design. The survey investigates six (6) key areas in the public-science domain, namely: engagement with S&T, impact of S&T on society, attitudes toward S&T, ethics in science, young people and science as well as gender issues in science. These thematic areas have appeared in a number of Eurobarometer survey waves and allow for both a national and cross-national comparison of longitudinal trends in science and technology issues across Europe (European Commission, 2013a). In addition to these broad areas of investigation in the main S&T questionnaire, selected waves also included special questions on specific science-public issues (see the 2001 report for special questions on *GMO crops* and the 2010 wave for issues related to *value and effectiveness of European public science investment*). The 2013 Special Eurobarometer Survey on Science and Technology (401, EB 79.2) was conducted in twenty-eight (28) European countries and yielded a final sample of 27 563 interviews that were conducted using computer-aided personal interview (CAPI) tools. The survey assessed general attitudes toward science and technology using a questionnaire comprising 17 questions associated with the specific science and technology themes under investigation (European Commission, 2013a). All questions were structured to be multiple-choice and respondents were presented with five (5) response options: four (4) response options ranging from extreme positive to extreme negative, as well as a *don't know* option. Where required, responses were designed to be multi-dimensional and these selected questions asked a number of question related to a specific measurement area (European Commission, 13a page Q1-Q7).

The results of the 2013 special Eurobarometer survey on Science and Technology (2013) indicate that Europeans are generally well informed and positive about the impact of science on society and scientific advancements. On questions related to issues of engagement with science and technology, respondents were asked a series of questions about their level of information about science, their interest in science and interaction with areas of science and technology. Most respondents across the EU-27 countries reported a higher interest in science developments, but simultaneously reported not feeling very informed about scientific developments. This was particularly evident in Hungary, Bulgaria and Romania, with 70% or more of the respondents indicating a lower sense of informedness and interest in science and technology issues. When asked about formal scientific education, 47% of total respondents in EU-27) indicated a positive response, with 71% of United Kingdom and 75% of Romanian respondents indicating secondary or tertiary education in a scientific field. When asked about sources of scientific information, as in the United States (NSF – SEI 2014), television still remains the main source of science information across Europe, with other traditional information sources following close behind (newspapers, radio, books and magazines). Newer technologies such as websites and blogs as well as social media platforms interestingly accounted for a smaller proportion of reported information sources. Countries such as Sweden and Denmark reported the highest proportion of responses attributed to these newer information sources, despite television remaining the primary source of science information in these countries (European Commission, 2013a).

The report further details trends in issues relating to the impact of science and technology on society, revealing that 77% of Europeans surveyed (EU-28) related a general sense of positive science impact in the 2013 survey. However, the survey also reports a general sense of ambivalence on questions relating to the level of civic involvement in science matters (European Commission, 2013a). The ambivalent viewpoint shares the idea that citizens should be informed about science, but differs on the level of involvement and consultation that should be employed in advancing scientific work across Europe. This indicator appears to be influenced by the level of educational attainment of the respondent. Denmark reported the strongest proportion of respondents (51%) calling for increased civic participation in scientific decision making, while similarly reporting the highest number of respondents with tertiary level science education.

General attitudes toward science and technology is a common measure in public understanding of science research and a series of questions were devoted to this in the Special Eurobarometer (401) Science and Technology Survey 2013. In a battery of questions resembling an index of *promise and reservation* on science and technology, Europeans generally reported a greater sense of promise and positive attitudes about the impacts of science on society. This is particularly noted under questions that relate to quality of life and issues of health and wellbeing. With respect to questions on the negative or unintended outcomes or applications of science, there was concern about science being used for terrorist activities (77%) and its environmental impact (74%) and impact on human rights (54%). Further analysis of the responses to the *promise and reservation* questions reveals a greater sense of promise among the respondents to this survey, with comparisons to the 2010 Eurobarometer indicating a shift toward more positive attitudes among Europeans. Among the respondents, 54% of generally agreed that ethical practices are vital to the continued success and safe application of science, particularly with emerging technologies such as biotechnology.

Young people in science received special attention along three (3) key areas, including governments' involvement in stimulating interest in science among youth populations, the question of whether young people's involvement in science better prepares them to secure employment, and the impact of science education on youth creativity. Most respondents (65%) reported that governments were doing too little to stimulate youth involvement in science. This was highest among respondents in Spain (83%) and Greece (78%). Both these countries also reported the highest increase in this negative opinion of government's role in promoting youth science involvement, whilst countries like Malta (+21%) and Lithuania (+13%) reported the greatest change toward a more positive opinion of government impact on youth science involvement (European Commission, 2013a). Questions relating to youth involvement in science and employment prospects reported a 59% agreement that youth interest in science may lead to better employment prospects. This opinion was particularly prevalent among Irish and Maltese respondents, both indicating 78% agreement with the statement and reporting significant increases in positive responses to this question compared to the results of the 2010 survey (European Commission, 2013a). Related questions about employment, youth interest in science and effective citizenship similarly received positive responses, with 68% of respondents indicating agreement with these statements. These attitudes were particularly high in Bulgaria (88%), Finland (84%), Latvia (80%) and Hungary (73%). The majority of Europeans (84%) further reported agreement with the statement that scientific education is important in stimulating young people's creative thinking (European Commission, 2013a). Gender issues in science were also addressed in the Eurobarometer 2013 study and indicated a high sense of agreement (86%) that scientific advancements should be gender neutral and address the needs of both men and women equally. Furthermore, this section also revealed that men are more likely (64%) to feel more informed about developments and more frequently report increased formal education in science and technology areas (51%).

The Eurobarometer Special Survey on Science and Technology 2013 represents a snapshot of European public attitudes to science as well as public opinions on selected scientific issues. It represents the latest investment in a rich, multi-year and cross-national data set. Proceeding from similar theoretical foundations to comparable surveys from elsewhere in the world, the Eurobarometer provides trend data within the European context and allows for meaningful comparison to other developed nations' outputs. While there have been some concerns and criticisms relating to methodological protocols employed in the Eurobarometer Survey, including the makeup of the sample, language use across the regions, and potential political and economic agendas of the European Commission, the general public and academic reception of the reports have been positive (Nissen, 2012 cited in Eden, 2014). The survey yields a large dataset, and particularly in the developed world context, provides valuable insights not only in the results of survey questions, but also into method protocol and public understanding of science research design characteristics (Eden, 2014).

3.1.4 United Kingdom: Surveys of public understanding of science 2000-2011

The United Kingdom has historically been one of the global epicentres of scientific literacy and public understanding of science research (Hurley, 1998). Following the developments of the Royal society report (1985) and the House of Lords Report (2000), discussed earlier, there have been many research studies conducted in Europe and the United Kingdom in particular. Many of these were based on large national samples within the UK or were part of sizeable multi-national studies such as the Eurobarometer and similar surveys (discussed above). Table 3.2 highlights some of the most recently conducted surveys in the areas of scientific literacy and the public understanding of science among UK based respondents since the beginning of the 21st century (BIS, 2011). While some of the surveys conducted were not specifically targeting scientific literacy, or had its focus on specific scientific areas (e.g. Cardiff University, 2010: views on climate change; European Commission, 2008: attitudes towards radioactive waste), all of these projects contained within them measures of knowledge and attitudes related to areas of public understanding of, and engagement with, science. This has yielded a robust multi-national and longitudinal series of data sets on UK and European public attitudes to various scientific areas that has proved a fertile foundation for ongoing research within this domain.

Publisher	Year	Sample size	Countries covered
World Values Survey	2000	1 000-4 000 interviews per country	97 countries including UK
Nestlé Social Research Monitor	2004	704 young people in the United Kingdom aged 11-21	United Kingdom
Office of Science and Technology (OST)	2004	1 831 UK adults aged 16+	United Kingdom
European Commission	2005	32 897 Europeans aged 15+; 1 307 in United Kingdom aged 15+	34 European countries including the UK
European Commission	2005	32 897 Europeans aged 15+; 1 307 in United Kingdom aged 15+	34 European countries including the UK
Institute of Physics	2005	1 023 adults in the United Kingdom aged 18+	United Kingdom
Organisation for Economic Cooperation and Development (PISA)	2006	400 000 students aged 15; 13 152 United Kingdom students aged 15	57 countries including the United Kingdom
Research Councils UK (RCUK) and the Department for Innovation, Universities and Skills (DIUS)	2007	2 137 United Kingdom adults aged 16+	United Kingdom

Royal Academy of Engineering and the Engineering and Technology Board (ETB)	2007	1 000 adults in United Kingdom aged 16+	United Kingdom
European Commission	2008	26 746 Europeans aged 15+; 1 306 in United Kingdom aged 15+	EU-27
University of York	2008	804 young people in England aged 13-14	England
Wellcome Trust	2009	1 179 UK adults aged 18+; 374 young people aged 14-18	United Kingdom
Cardiff University	2010	1 822 adults in United Kingdom aged 15+	United Kingdom
Department for Business, Innovation and Skills (BIS)	2010	988 adults in United Kingdom aged 15+	United Kingdom
Engineering UK	2010	5 789 respondents aged 7+	United Kingdom
European Commission	2010	26 671 Europeans aged 15+; 1 311 in United Kingdom aged 15+	32 European countries
European Commission	2010	26 671 Europeans aged 15+; 1 311 in United Kingdom aged 15+	32 European countries
Department for Business, Innovation and Skills (PAS 2011)	2011	2 103 United Kingdom Adults aged 16+	United Kingdom
European Commission	2014	26 671 Europeans aged 15+; 1 311 in United Kingdom aged 15+	33 European countries

Table 3.2: Recent International Studies (adapted from BIS, 2011)

Notable surveys include the World Values Survey (2000), the Eurobarometer surveys on public understanding of science, The OECD-PISA surveys, the Wellcome Trust survey as well as the Department for Business, Innovation and Skills / IPSOS-MORI surveys on public attitudes to science in the United Kingdom. For the purpose of brevity and in the interests of reviewing the most recently available empirical work, not all the above surveys will be discussed in detail. The below review will therefore only briefly cover the results of the latest Eurobarometer Survey on Science and Technology (401, EB 79.2) as they relate to the UK public, and then go on to discuss the methodology and results of two (2) large surveys of the UK public understanding of science: The OST-Wellcome Trust survey (2000) as well as the BIS-IPSOS/MORI study (2011).

Within the total of 27 563 participants in the 2013 Eurobarometer survey on Science and Technology (401, EB 79.2), the United Kingdom surveyed 1 306 respondents, 15 years and older. On measures of informedness on science and technology issues, 56% of UK participants reported being well informed or fairly well informed, higher than the EU-27 average of 40%. Similarly, on measures of interest in science, scores for the UK respondents were 11 percentage points higher than the EU-27 average. Comparisons on levels of science education indicate that 71% of UK participants had some form of formal science education (at secondary, tertiary or some other level) compared to the EU-27 average of 47%. United Kingdom participants reported a positive result with respect to the influence of science on society, with 76% indicating a positive influence, one percentage point lower than the EU-27 average. The attitudinal *Index of Promise and Reservation* reveals that UK participants appear to be more positive about the influence and value of science, although they expressed a greater concern about the unintended consequences of science within society. Likewise, many UK respondents also expressed a high level of agreement about the ethical standards in practice by the scientific community compared to average scores across all other countries measured. Interestingly, on questions relating to the influence of science and science education on young people, respondents in the UK reported consistently lower scores than the EU-27 averages. This has further revealed a downward trend from the 2010 survey for UK participants with respect to the benefits of science education on young people (European Commission, 2013a). Despite the understanding that trend data will fluctuate between measurement waves and across surveys of related subject matter, careful review has been mooted in order to ensure the UK maintains standards and performance on these key science and technology indicators (Coughlan; 2013). Whilst the results of the Eurobarometer have been discussed previously, the United Kingdom country analysis data reveals important trends in public opinion and attitude with respect to science and technology. This will however, not be discussed in greater detail in this section[15].

In 2000 the Wellcome Trust and the UK Office of Science and Technology jointly sponsored a study investigating the public understanding of science in an effort to best tailor science communication aimed toward public consumption (Office of Science and Technology & The Wellcome Trust; 2000). In the foreword to the report, Lord Sainsbury and Dr Dexter highlight the importance of the report together with the House of Lords Report (2000) and the White Paper on Science and Technology (2000) as key foundations toward a period of consultation between the various British science and technology actors. The Wellcome Trust – OST study was designed to include two components – the first looked at input mediums for science communication toward the general public, and a second survey of outcome-competencies related to public understanding of science among the British public. While the initial input survey on science communication methodologies is noted, it will not be discussed as it relates only indirectly to the outputs being reviewed here. The survey on public attitudes to, and understanding of, science and technology in the UK yielded a total response of 1 839 responses from a nationally representative sample. The initial phase of this research was based on qualitative interviews that informed the larger quantitative study. The results of the survey

[15] Detailed discussion of country specific results are outside of the scope of this chapter and will not venture beyond these summary results.

were analysed using factor and cluster analysis that revealed six (6) attitudinal clusters informing the thematic areas on which the report is based (Office of Science and Technology & the Wellcome Trust; 2000). These attitudinal groups are presented below in table 3.3 to further the discussion to follow:

Attitudinal groups	Definitions and characteristics
Confident Believers	Positive, self-confident and outward looking, the Confident Believers (n=17 %) are interested in science because of the benefits it brings; their interest in politics relates to a tendency to have faith in the regulatory system. They tend to be well off, well-educated and middle aged.
Technophiles	This is the largest group (n=20%). They are confident, Pro-science and well educated in science, but sceptical of politicians. They tend to be confident that they know how to get information when they need to; although they need reassuring that the regulatory system exists and works effectively.
Supporters	This relatively young group (n=17%) tends to be 'amazed' by science, engineering and technology and feels confident enough to cope with rapid change. They also tend to believe that the Government has things under control. They express the most interest in the medical Sciences and tend to be slightly more interested in the physical sciences – especially engineering – than others.
Concerned	This is the smallest group (n=13%) and mostly female (60%).They have a realistic and positive attitude to life but are sceptical of those in authority. Their social grade, household income and education levels tend to mirror the population as a whole. They are interested in a whole range of topical issues, and they know that science is an important part of life, especially for their children.
Not Sure	This group (n=17%) tends to have the lowest household incomes, the lowest level of education, and generally form part of the semi- and unskilled labour force or are unemployed. They are neither 'anti-science' nor 'pro-science' largely because the benefits of science are not always apparent in their daily lives.
Not for Me	This group (n=16%) mainly comprises those aged 65 and over and is predominantly made up of women but also includes slightly younger men. Like the 'Not Sure' group, they are not particularly interested in political and topical issues or in science. However, their lack of interest in science does not stop them appreciating its benefits for the future and its importance to young people.

Table 3.3: Attitudinal group clusters
(Table adapted from Office of Science & Technology and the Wellcome Trust report; 2000)

The quantitative study yielded a nationally representative sample of UK adults by interviewing 1 200 people, and conducted additional booster samples of 200 members of minority groups and 400 individuals in Scotland (Office of Science and Technology & the Wellcome Trust; 2000). The questionnaire was constructed to assess three (3) attitudinal aspects: issues of personal confidence and coping with change; attitudes, interest and perceived benefits of science as well as attitudes toward authority, the government and the regulatory environment surrounding science. Results of the survey indicate that respondents' interest in scientific fields do not vary considerably with those of other developed nations. The majority of respondents reported a higher interest in *health issues* and *new medical discoveries* (52% & 46% respectively). As in the United States (NSF-SEI survey, 2012), respondents did not report high interest in *new inventions and technologies* or *new scientific discoveries* (24%, 22% respectively), instead reporting higher interest in issues of *Sport*, *Welfare* and *Education*, in increasing order of interest. *Interest in science* and the *perceived benefits* of science was found to be correlated, as increased *perceived benefit* of scientific fields usually followed increased *interest* in those same areas of scientific achievement.

Among the sample of the United Kingdom population there was a high reported appreciation for the personal and social benefits of science. Using a 16-item *index of scientific promise and reservation,* the Wellcome Trust study revealed a positive appreciation for the benefits of science among respondents. However, there also appears to be some degree of reservation relating to the *ability of the general public to understand science*, the *level of conflicting information about science* as well as *the rate of scientific advancement*. This uncertainty regarding the value of science is further reinforced by a high number of respondents indicating *I am not interested in science and don't see why I should be,* and that *the achievements of science are overrated* and (20% and 22% respectively). The majority of respondents (80%) however believe in the importance of science in growing the UK's economic prospects into the future and 70% of respondents reported support for basic scientific research. A similar quantum of respondents further agreed with statements reflecting the positive role science will play in future employment and human benefits. Concerns were highlighted about the government's ability to influence the direction and progress of scientific advancement (40%) as well as the perception that scientists do not fully appreciate the risks inherent in their work (56%). The influence of the private sector on scientific advancement and funding was further illustrated; with 61% agreeing with the statement science *is driven by business interests*.

The Wellcome Trust OST study (2000) reflected an overall increased public understanding of science and an increased positive appreciation for scientific work when compared to previous research conducted among the UK public. The study revealed that attitudes to science are in some part driven by basic personal attitudes. These highlighted 6 (six) attitudinal cluster groups from which to begin to understand the segmentation within the UK public in relation to scientific attitudes, interest, knowledge and awareness. The authors do however point out that whilst the six (6) attitudinal groups do show different demographic and social characteristics, communication approaches and the content of scientific communication do not necessarily need to be varied for each cluster group.

The notion then of many publics, rather than one homogenous public, is also encountered within the UK population, just as it has been highlighted among the South African population (Reddy *et al*, 2009).

Since the 2000 Wellcome Trust study, there have been other studies in the UK with a focus on varying aspects of the public/science relationship. However a more recent study, *Public Attitudes to Science (PAS) 2011,* conducted jointly by the UK Department for Business, Innovation & Skills, IPSOS/MORI and the British Science Association continues a series of research studies on the public understanding of science in the United Kingdom. This study is uniquely positioned among the many others conducted in the UK as its series is related to the original Wellcome Trust study and trends across the intermediary decade can be observed when the results of the two studies are juxtaposed. The PAS 2011 study adopted a mixed methodology approach in its research, consisting of an international literature review study, general public workshops and discussions as well as a national quantitative survey of UK public attitudes and engagement with science (BIS, 2011). The survey yielded a sample of 2 103 respondents from across the UK, aged 16 years and older. Within the sample, 1 798 interviews were conducted with adults of all ages and 305 interviews were conducted with young people aged between 16 and 24 years of age using computer aided personal interview techniques (CAPI). The aims of the research were multi-fold, but focused on general public definitions of science, the public-scientific community relationship, impacts of science on daily life, scientific information sources, public confidence in science, awareness of scientific methods and public perceptions of science policy (BIS, 2011). As this study is the fourth product in a series of research studies, the questionnaire used many of the previously used measures and added a limited number of new questions to the 2011 questionnaire. The interviews lasted between 35 and 40 minutes and, while limited respondent information was recorded, all personal information was declared confidential. The questionnaire, despite being asked using CAPI tools, consisted of 38 questions; some were open-ended, with probing toward the data capturer being able to make a selection(s) while other questions relied on multiple-choice options presented to the respondent on stimulus cards.

Similar to the Wellcome Trust study (above), the BIS (2011) study also produced a public segmentation in relation to perceptions of science among the general population using cluster analysis. The analysis revealed six (6) attitudinal clusters from within the 2011 study, presented in Table 3.4 below:

Cluster Name	Cluster characteristics	% of UK Population
Concerned	The Concerned are more likely to feel overexposed to science, are less interested in careers in science, are more worried about the intentions of scientists, and are less convinced about the economic benefits of science.	23%
Indifferent	The Indifferent are most different from other clusters in their general attitudes to life, are less likely to take an interest in science, feel confused by science, are less informed and more likely to regularly read tabloid newspapers.	19%
Late Adopters	These have more negative attitudes towards science education, but show an interest in scientific advancements, take a broad view of what constitutes science, their interest in science tends to focus on environmental and ethical issues and they are less likely than the average to get most of their science information from print newspapers.	18%
Confident Engagers	Confident Engagers take a strong interest in Science, are strongly positive about the role of science in society, show high levels of confidence and trust in scientists, tend to be content with current levels of information, are keen to contribute to public discussions about science and more likely to access science information on the internet.	14%
Distrustful Engagers	Are enthusiastic about science and see it as beneficial to society, feel well informed about science, have low levels of trust and confidence in scientists, are interested in specialist science content and access this mostly through electronic media	13%
Disengaged Sceptics	Do not feel informed about science and are often overwhelmed by it, have strong concerns about scientific developments, favour a relatively conservative approach to science, do not personally contribute to public discussions but want to know the public is being listened to. Most science information is accessed via old media.	13%

Table 3.4: Attitudinal groups clusters - table developed from BIS report: *Public Attitudes to Science*, 2011

These six attitudinal cluster groups are based on the outputs of cluster analyses performed in seeking to identify similarities in groups of individuals who have, through their responses, displayed similar attitudes to science. The similarities between the attitudinal clusters from Table 3.3 and Table 3.4 can be highlighted when compared, with the largest population segment continuing to be confident about science, well-informed, but sceptical about scientists and the regulatory environment that aims to manage scientific outputs and contribution to society.

The report further details results from the study along six (6) themed chapters that will be briefly discussed here. The first of these looks at how the UK public defines science. The results indicate that while no single definition of science was common in the research results, many respondents acknowledged the multi disciplinarily nature of science as well as the importance of the scientific methods and processes that may assist in defining the enterprise. The majority of respondents reported a beneficial contribution by science to society (80%) while more than half (54%) agree that the benefits of scientific advancement outweigh the risks. Moreover, the vast majority (88%) agree that scientists make a positive contribution to society, showing a consistent positive trend since the 2000 study. The report does, however, highlight the lack of awareness among the general population about the methods and processes employed by scientists in the execution of their work. Concerns were also raised about the funding of scientific work, as well as the implications for public policy and future advancements within the various fields (BIS, 2011).

Scientific information sources is a common question globally, and one that has been maintained within the series of studies within the UK. Eighty-two percent (82%) of respondents indicated an interest in science and scientific advancements, while 68% of respondents indicate that it is useful in their daily lives. However, 51% reported that they feel less informed about science and would like to see increased scientific coverage in the media. Among the sample it was evident that informedness depended significantly on whether the specific topics were topical in daily discourse (like global warming and GMO foods) while conversely it was found that topics that dealt with frontier science were less likely to be common knowledge among the vast majority of respondents (56%). Since 2008, the number of respondents reporting a general informedness about science has decreased, despite greater reported access to scientific information. Many respondents (62%) reported that this may be due to the rate of scientific advancements as well as the increased degree of specialisation across the varying scientific disciplines. The BIS survey also looked at most regular sources of scientific information among the UK population and indicated that traditional media (television - 53%; print newspapers-33%; radio -14%) still account for the largest share of information sources. New media sources such as internet websites and microblogging sites only account for 19% of regular information sources, with men (24%) reporting a greater online science appetite than women (16%) (BIS, 2011). Similarly, age also plays a role in determining most common source of scientific information, with younger groups reporting greater online scientific content consumption compared to those older than 24 years old, with those aged 55+ reporting more frequent use of print newspapers as a source of science content. However, despite these age-related disparities, traditional media sources still overwhelmingly remained the most frequent information source across the sample (BIS, 2011).

Trust in the scientific community and scientists was also assessed in the study and results indicate that trust may be related to the institutional or scientific community affiliations wherein which the information originates. Within the sample group, 47% indicated that they generally find scientific information true, while 34% disagree and adopt a more sceptical view. However, 52% of the respondent’s further report that information received would be more readily assimilated if it had in fact passed through a peer review or similar mechanism to verify the findings presented. Results further indicate that respondents generally feel the most credible source of scientific information is within scientific journals; however, the study also notes that access to these materials by the general public is limited and thus mainstream traditional media and online sources remain the core access point for scientific information.

With regard to public involvement and consultation, many Britons report a degree of cynicism regarding the impact of public-science consultations. There is general agreement that research should be directed toward serving the public interest (73%), and many respondents report that public consultation would aid in fast-tracking any potential social advances that may be derived from scientific work in the UK. Barriers to effective public participation have been recorded as mostly associated with lack of general public understanding of scientific issues (26%) as well as lack of public interest in scientific issues (19%). However, 50% of respondents report that while they applaud the fact that the public is being consulted, they would personally prefer not to be part of the public-consultative process.

Looking at the influence of science on the daily life of UK respondents reveals that 50% had visited a non-formal science learning centre such as a museum, botanical garden or zoo in the preceding 12 months (BIS, 2011). One-quarter of respondents (25%) indicated that their experiences of learning science during formal schooling had '*put them off science'* and had led them to question the applicability of school science in their daily lives. A large majority (70%) of the total sample (n=2 103) believe that a career in science would be *very interesting*, however, this figure does decrease among the 16-24 year old cohort of respondents where only 651%<?> agree with the statement. The impact of science and scientific developments on economic growth is loosely understood, with 75% of respondents agreeing that it makes a positive contribution to the economy. A similar percentage agrees that public funding for scientific activities should continue toward advancing the general body of knowledge. This is of particular importance as many Britons are in favour of overall reductions in government spending, despite the abovementioned support for publically financed research activities.

While the results of the Public Attitudes to Science (BIS, 2011) reveal a UK public that appears to be supportive of the scientific enterprise, it is clear that it maintains certain long-standing reservations about the activities of scientist and scientific institutions with respect to potential impact on society. The interest in scientific activities among respondents in this study appears to have increased since the previous release of the study in 2000 and 2008, as well as the public perceptions about its ability to understand and assimilate scientific information. Access to information remains via traditional media types, though there is evidence emerging that among the youngest segments of the population this is advancing toward a more electronically based access protocol. There is furthermore evidence strengthening the public perception of the benefits of science over the potential risks associated with certain advances, both in terms of knowledge advancement as well as social and economic impact of science on society. Attitudes to science appear to be fluid and may shift between positive and negative depending on the specific scientific topic being addressed, the institution presenting the information and the perceived credibility of the information received. The study similarly presented six (6) attitudinal groups within the UK general population (see Table 3.3 above) within which targeted communication modalities and messages may prove useful for developing more positive attitudes toward science among the specific demographic groups in the least positive segments.

3.1.5 Japan: Public understanding of science research in the *Land Of The Rising Sun*

Following World War 2, Japan recorded a period of unprecedented economic growth, becoming the second largest economy in the world, just behind the USA. While much of this success related to the geo-political situation during the period between World War 2 and the end of the Cold War, the economic, social and political progress of Japan accelerated tremendously during this time. However, by the end of the Cold War, Japan began to experience the impact of overinflated real-estate and stock market prices and entered a period of gradual economic decline during the early 1990s (Otsubo, 2007). Despite this Japan has maintained a high human development index (HDI), ranking 10th globally, just behind Switzerland and Sweden (UNDP-HDI, 2013). Linked to this, Japan has an extended history of scientific development, learning and teaching which has accelerated progress, which despite recent economic deflation, has continued to influence Japanese society. Early efforts by the Meiji Government (1860-1912) toward enforcing compulsory education across Japan from as early as 1872 led to a highly educated population as well as a higher proportion of tertiary education, vocational training and educated women than in many other developed countries during this period (Nagahama, H, 1994). Much of this effort was directed toward leveraging a literate and capable workforce and positioning Japan favourably in terms of economic and military capabilities with respect to its Western counterparts.

As the study of *scientific literacy* and *public understanding of science* advanced across Europe and the United States of America, so too did interest in these metrics reach the Far East and attracted the interest of researchers working within the rapidly developing economies in this region. As Japan altered its science policy from a position of 'catching up to the west' to a more contemporary policy of 'leading technological advancements', so too was it important to understand Japanese perceptions of domestic excellence. As much of this related to areas of scientific and technological progress and advances, researchers' interest evolved into the study of scientific literacy and public perceptions and understandings of science in Japan since the late 1980s (Nagahama, H, 1994).

The first survey of scientific literacy and the public understanding of science in Japan were conducted by the National Institute of Science and Technology Policy (NISTEP) in 1991. The survey was designed to assess the levels of scientific literacy and public attitudes to science in the Japanese population, as well as to provide a baseline international comparison (NISTEP, 2002). Due to the need for international comparison, many of the measures and questions used in the Japanese questionnaire were adopted from the United States *NSF-SEI* and the European Commission Eurobarometer Surveys, which conform to the models of scientific literacy proposed by Miller (1983) and Shen (1975), (Kawamoto et al, 2013). The survey was repeated by NISTEP in 2001, and it is this latter survey that this review will focus its attention on. The 2001 *Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan* yielded a nationally representative sample of 2 146 respondents of both women and men, aged 18 years and older. The survey employed a 2-stage random-stratified sampling technique and conducted face-to-face interviews between February and March 2001 (Ishii, 2002). Due to the requirement for international comparability, the surveys adopted many of the themes from the NSF and Eurobarometer surveys. This included items on level of interest; sources of information; public attentiveness to science; basic science knowledge assessments; measures of attitude to science; risk/benefit awareness of science and government support for science (NISTEP, 2002). These themes allowed the authors to make meaningful comparisons with similar questions in the American and European surveys. Some of these results are discussed below.

Results from the 1991 and the 2001 NISTEP surveys indicate generally lower scores for the Japanese population when compared to responses to similar questions in both the USA and European populations, likely as a result of cultural distance between the Western and Eastern approach to basic learning and scientific literacy. On questions related to levels of interest and informedness on a number of issues, Japanese respondents rated science and technology issues very low, between defence and atomic energy issues. The highest rated issues on this scale were environmental pollution, economic issues, medical discoveries and issues of schooling and education. Interestingly, for science and technology, 44% indicated a level of interest in these issues, but only 28% reported being well informed about recent developments within this domain. Comparing the Japanese scores to their international counterparts', in the 1991 survey 50% of Japanese respondents indicated an interest in scientific issues, 11% lower than both the USA and European (average) scores of 61%. In the 2001 survey, the Japanese scores fell further, to 44%, and while both the US and the European scores recorded a similar decreased during this period, Japanese scores were still significantly lower (NISTEP, 2002).

Level of understanding of basic scientific concepts has been employed in scientific literacy surveys since the earliest measures were developed (Miller, 1998; Roberts, 2007). Both the 1991 and the 2001 NISTEP surveys employed a 15-item battery of statements relating to scientific concepts and respondents were asked to indicate whether the statements were *true* or *false*, with a *don't know* option also provided. Japanese respondents' average score for reporting correct answers to this battery of questions was 54% in the 2001 survey. While this compared favourably with selected countries, it was still lower than a number of European countries and the USA (NISTEP, 2002). It must be noted, however, that the majority of scores in the international comparison tables were below 70%, indicating a generally lower performance on questions of this nature across national surveys. Furthermore, only 11 of the 15 items in the Japanese survey were comparable with similar international surveys. Using *cluster analysis*, it was revealed that among the 15 questions in the Japanese survey 4 cluster groups were identified, depending on the level of difficulty associated with answering the specific questions.

Results from the 2001 NISTEP study reveal generally positive attitudes relating to areas of science and technology (NISTEP, 2002). Questions on whether a) *science has made the world better b) life more comfortable c)provided more opportunities for future generations,* and *d) if science has made vocational environments more interesting,* attracted positive responses from more than 50% of the sample group. However, on questions relating to the *risks* and *benefits* of scientific advancement, the Japanese appeared more ambivalent and, while reporting a general sense of support for scientific enterprises, showed a sense of risk awareness hovering between the potential harmful impacts of science and an area of indecision, where risks are about equal to the benefits. This was particularly apparent when it came to questions relating to genetically modified (GMO) food products. Most respondents reported that the harmful impacts may outweigh the benefits of GMO food products, with 16.3% indicating a *don't know* response to this question (NISTEP, 2002).

Similar to the NSF-SEI in the USA and the European Eurobarometer surveys, in the NISTEP survey data was also collected on the most popular sources of scientific information used by the general Japanese public. As in the USA and Europe (and almost all PUS surveys globally) older media channels continue to be the most important source of scientific information. Japanese, like many others, rate television as the most important information source of scientific information (91%), followed by newspapers (70%), magazines/ journals (35%) and books (13%). This survey was conducted in 2001, when internet penetration was not as common as it is in 2016, and this media accounted for 12% of most frequently accessed information sources in 2001. However, when asked *which information source would you prefer to use in the future*, 31% of respondents indicated that the internet would become a major information source of science and technology information (NISTEP, 2002). On questions related to public opinion, as to who should be responsible for promoting public understanding of science among the Japanese population, 43% of respondents indicated that the primary responsibility should rest with the government; 38% felt scientist and researchers should play a greater role; and 34% indicated that educators should make greater efforts toward science popularisation. Interestingly, only 29% and 27% of respondents indicated that the mass media and the general public, respectively, should play leading roles in promoting an enhanced public understanding of science in Japan.

In 2007, Kawamoto *et al* conducted an empirical research study entitled *Survey of current status of scientific literacy and development of educational program by tendencies in social activities*. The study was conducted by the *Research Institute of Science and Technology for Society* of the Japanese Science and Technology Agency programme, *Scientific Literacy of the 21st Century*. Under this programme, the broad aim of the study was to investigate the principal requirements of practical science communication activities of the Japanese public by understanding scientific literacy in terms of its importance in society. The outcome of the study was the development of a 3-factor/4-cluster model by which to understand Japanese public's scientific literacy, which was similar to the Wellcome Trust and Department for Business, Innovation & Skills, IPSOS / MORI study in the UK (2000 and 2011). Similar to the NISTEP (2002) study, Kawamoto *et al* surveyed 1 286 adults aged 18 years and older using a two-stage random stratified sample from the *Basic Residents Register*[16] to yield a nationally representative sample. However, instead of conducting face-to-face interviews, Kawamoto *et al* employed a postal survey method, whereby 4 000 questionnaires were dispatched, with an eventual response rate of 32.15%, compared to the 71.5% response rate in the NISTEP (2002) survey which used face-to-face interviews. Adopting learnings from studies in the UK, the Eurobarometer, PISA and the NSF studies, Kawamoto *et al* adopted a definition of scientific literacy that included all three aspects of the Miller – Shen model which included measures of *knowledge, attitudes* and *the impact of science on society*. The definition adopted within the study was: 'Scientific literacy is the *capability of making a social judgment and taking action on issues involving science and technology by linking basic scientific knowledge and methodologies to interests and attitudes, including those related to science.*' (Kawamoto *et al*, 2011).

[16] Similar to Census data

	Questionnaire set	Number of questions	Focus areas
1	*Field of interest.*	15	4-point scale on degrees of interest toward various scientific and on-scientific fields. Response options included 2 agree options and 2 disagree options, with no neutral option provided.
2	*Interests and attitudes*	35	Information about sources of information as well as the amount of information accessed through particular media types. Questions of practical scientific literacy (everyday application of knowledge), attitudes toward science and frequency of attendance at social activities like museums and public debates and community meetings were also assessed. Respondents were also asked to rate their own skills in various areas, including, but not limited to, science and technology areas.
3	*Evaluation of science and society*	15	Questions about the value of science in daily life and the influence and contribution it made to the Japanese nation were assessed. Questions relating to trust in scientists, media and government were also assessed.
4	*Understanding of scientific knowledge*	13	13 true or false quiz-type questions (similar to NSF) were included.
5	*Understanding of scientific methodology and social judgment*	9	Questions similar to the PISA questions were used to create practical situations of applying scientific knowledge contained within stimulus material. Response types vary per question, however were limited to True/ False responses, and questions requiring respondents to draw graphs or explain the contents of the stimulus material

Table 3.5: Questionnaire structure of 2007 Kawamoto *et al* study

The questionnaire consisted of five (5) parts, each containing a series of questions related to a particular dimension within the scientific literacy definition. Table 3.5 below summarises the questionnaire structure as well as the specific focus of the questions. In addition to the questions listed in Table 3.5, basic demographic information was also collected at the end of the questionnaire that aided in developing the clusters within the results. Using factor analysis techniques, factors were extracted from the 65 questions in the initial three (3) question groups and respondents were then classified into 'scientific literacy clusters' based on the scores attained in each of the extracted factor groups. The three factor groups used were based on the question groups in the questionnaire; including a 'scientific knowledge' factor, a 'social factor – related to interest and social involvement in science, and the third factor of 'science appreciation', related to appreciation of science as well as attitudes to scientists (Kawamoto *et al*, 2011). These factor groups were then constructed into a 3-factor/4-cluster model of scientific literacy within the Japanese population, similar to the UK studies discussed above.

The results of this study were intended to provide the basis for future communication strategies relating to science, to improve scientific literacy among the Japanese population. Results indicate that though Japanese participants have a high knowledge of science concepts, they however might not be particularly active in the support of science matters and public involvement (Kawamoto *et al*, 2011). A second finding in the study was that science-appreciating factors greatly influenced the science knowledge and social factor among Japanese, indicating that attitudes and knowledge may be related to how science and scientists are perceived by the general public.

Beyond the above-mentioned studies, since 2000 there have been a limited number of other empirical studies conducted in Japan dealing with scientific literacy, public understanding of science as well as science communication areas of interest. NISTEP has, since 2009, launched an internet survey monitoring various aspects of science communication in Japan, beyond scientific literacy. These include attentiveness to scientific issues - particularly those of significant social importance such as the impact of the Japanese tsunami of 2011 - impact of science on society, and expectations of science's impact on society. The Trends in International Mathematics and Science Study (TIMMS) survey, which collects information on students at grade 4 and grade 8 every four (4) years toward assessing math and science achievement among primary and secondary school learners, has also been implemented in Japan since 1995, with the most recent survey completed in 2011[17]. In addition to these, public perception surveys had also been conducted by the Office of the Japanese Prime Minister in 1976, 1981, 1986, 1987, 1990, 1995 and 1998. The Japan Science and Technology Agency (JSTA) has also been active within public understanding and promotion of science activities since its inception in 1996, and since 2011, to date, has been highly active in promoting the Japanese Science and Technology Basic Plan toward fostering an increased public understanding of science and promoting scientific careers, science communication and awareness in Japan.

What is however apparent, and relevant to many countries in the Far East, including Japan, is that a number of these studies are exclusively published in Japanese, with no English versions available for review. While this does present a minor limitation, the above review of empirical work from within Japan does present a cursory view of the status of public understanding of science and scientific literacy research in the island nation as well as its comparability in terms of method protocol and outputs of empirical studies relative to other developing countries discussed above.

3.1.6 Australia: large surveys of public understanding of science and scientific literacy

As a result of its colonial past and being part of the Commonwealth, Australia enjoyed many benefits of its ties to the United Kingdom and Europe through trade and political relations that has shaped modern Australia in numerous ways. A country of 23 million people, Australia has developed into a formidable global entity, with a stable and successful economy and ranking 2nd on the Human development index (UNDP-HDI, 2013). Since the 1970s, Australia has undergone a number of changes domestically, endeavouring to reinvent itself and its institutions toward adapting to a changing world (Gascoigne & Metcalse, 1994). Science and scientific institutions have also adapted under these changes and have impacted on science communications practices as well as science education, the public understanding of science and scientific literacy. Early surveys of public opinion

[17] TIMMS surveys will be discussed later in this chapter as it pertains to the South African context

toward science in Australia revealed that a large portion of the population failed to appreciate science and technology adequately and did not view careers in science to be attractive toward gainful employment prospects (NBEET, 1993). Much of this anxiety was found to be linked to a limited public understanding of science, and following this, a number of projects were established in Australia that set out to develop a more positive public understanding and appreciation of science and technology among Australians (Gascoigne & Metcalse, 1994). While much of this work was related to science popularisation efforts in conjunction with the mass media services, education was also seen as a key driver of these goals, and the majority of efforts to promote scientific literacy in Australia were focused within the education domain. Among the earliest efforts to measure the general public understanding of science in Australia were some conducted by the Australian National Board of Employment, Education and Training, who commissioned a study entitled "*What do they know? : The understanding of science and technology by children in their last year of primary school in Australia*". This report assessed educational outcomes of primary school education in Australia as it related to the general understanding of science and technology, and set a baseline for measurement of learner scientific achievement in Australia.

Similar to a number of other developed economies, Australia participates in the PISA surveys and, since its inception in 2000, has performed consistently well in every wave of the survey. In the most recent wave, Australian students on average, scored significantly higher than their peers in other OECD countries, having been outperformed by only four territories - Finland, Hong Kong, China and Canada (PISA, 2012). On measures of scientific literacy and scientific proficiency, 3% of Australia´s students achieved the highest scientific literacy proficiency level in PISA, which was above the OECD average of 1%. At Level 6, students can consistently identify, explain and apply scientific knowledge and knowledge about science in a variety of complex life situations. The majority of students in Australia ranked at proficiency level 4 or level 5, indicating generally higher scientific literacy proficiency among Australian learners. Another large international survey frequently administered in Australia is the TIMMS survey, wherein 6 146 learners were surveyed in the 2011 round of this survey's 4-yearly cycle. Australian learners scored significantly higher than 23 other participating countries, and were ranked 19 overall out of the total 43 countries which has been a fairly consistent performance over the last 4 waves of the TIMMS survey (Thomson et al, 2011). A further initiative in Australia has been the *Progressive achievement test in science* testing system that seeks to identify students in the lower schooling grade's abilities in relation to expected science educational outcomes. While this is not a large survey of scientific literacy, it is a unique feature within the Australian science education system and public science literacy initiative not seen in other countries. These tests are based on multiple choice questions that require various skills to be applied to stimulus material related to required science educational competencies that are very similar to the PISA questionnaires. The results of these tests are focused on the individual participant rather than a population of young people (as in PISA or TIMMS) and directed interventions are then identified toward addressing particular strengths or weaknesses of particular individuals.

In 2010, the Australian Academy of Science commissioned a survey, conducted by AusPoll and entitled Science Literacy in Australia 2013. The survey presented the results of a survey similarly conducted in 2010, and provides comparisons across the two surveys on basic questions of science literacy. Important to note is that this survey only collected information on science knowledge factors, and not attitudinal, information sources or other related data points found in other surveys of the public understanding of science. The questionnaire used was adapted from a similar survey carried out by the California Academy of Science in 2009. The Australians adopted an online design in implementing their survey methodology, which, unlike South Africa, has an internet penetration rate of 82.3% among both rural and urban populations, and this was deemed feasible for a reliable survey design (Wyatt & Stolper; 2013). The sample was weighted to reflect the national demography, taking into account age, gender and domicile location (rural or urban). The total sample achieved was 1 515 and was representative of the Australian population. Results of the survey indicate that while most Australians have a basic grasp on scientific facts and may possess a degree of scientific literacy, approximately 30% of respondents still were not able to provide the correct answers to many of the knowledge questions in the questionnaire. In comparing the 2013 results to the 2010 survey, a statistically significant decrease in overall scores was observed, indicating a declining scientific literacy rate in Australia between 2010 and 2013. As with many other surveys of *basic scientific literacy* (as opposed to surveys of *public understanding of science*) generally younger participants who are male and better educated achieved higher scores compared to their counterparts within and across those demographic groups (Wyatt & Stolper; 2013). However, despite this general finding, the authors also report that the younger age groups within the study, and particularly the 18-24 age groups displayed a higher proportional drop in scientific literacy compared to the same demographic group in the 2010 survey (from 74% in 2010 to 62% in 2013). Despite this, Australians generally appear to have a high sense of scientific literacy as reported in 2010 and 2013, and indicate an acute awareness of the value and contribution science makes to the Australian economy and modern way of life (Wyatt & Stolper, 2013). However, the detailed results of this survey will not be discussed in this review as it provides limited value to the current project due to its exclusive focus on *scientific knowledge* areas rather than the extended *social* and *attitudinal* spheres of this research arena.

During June and July of 2010, the Australian National University, in conjunction with its College of Physical and Mathematical Sciences and the College of Arts and Social Sciences, ran the 8th ANUpoll, a quarterly public opinion survey conducted since 2008. The ANUpoll is a nationally representative survey of Australians 18 years and older, with a focus on public opinion in relation to the many policy issues facing Australian society. The 2010 wave, with its focus on what the Australian public views as important in relation to science, scientists and climate science, surveyed 1 200 adults via telephone interviews and yielded a response rate of 43.2% (Lamberts, Grant & Martin, 2010). The survey team employed a *random digit dialling* (RDD) approach in conducting the fieldwork as it presented more accurate and reliable coverage and representation in relation to the overall sample design and national demography. In Australia, this approach is widely accepted due to the high penetration of fixed and mobile telephones, and overcomes the problems associated with unlisted and private numbers by not being dependent on a telephone listing but rather on *random digit dialling* within a defined exchange area (Cummings, 1979).

The survey presented its findings as well as comparisons to similar international opinion surveys toward understanding the implications of the results within the specified policy context. The questionnaire consisted of forty-six (46) questions, with multiple response options either requiring single selections or multi-selections depending of the question context. While conducting telephone interviews, fieldworkers used *computer aided personal interview* (CATI) software to record respondents answers to the questions. The first section covered the political situation in Australia, and asked questions dealing with public satisfaction in relation to the current Australian leadership, and problems facing the country – from housing, employment, youth issues, education etc. These were presented as multiple choice-type questions. The second section made up the major focus of the questionnaire, assessing public opinion in relation to science and specifically science knowledge, interest and attitude, consisting of 34 of the total 46 questions (74%). Questions in this section were again multiple-choice. However, response options were limited to single selections on appropriate scales ranging from scales of agreement/disagreement to predefined response categories, as well as refusal and *don't know* options. The third section of the questionnaire asked questions relating specifically to issues of *science and climate change* as well as issues related to public policy and science. This section had two (2) questions relating to climate change issues and seven (7) questions relating to public policy issues, having similar response options to the preceding section in the questionnaire.

On questions relating to *knowledge and interest in science*, Australians indicated a general interest in areas of science including medical science and discoveries, environmental issues, issues of crime and general scientific discoveries, 50-70% of respondents indicating interest in these fields. This was significantly higher than reported interest in film, politics, music or sports issues, which all scored well below 40% in terms of public interest ratings (Lamberts, Grant & Martin, 2010). In a series of questions that appraised public opinion about the relative contributions various professions made to Australian society, *scientists*, *doctors*, *teachers* and *engineers* were rated considerably higher than the police force, politicians, members of the various religious fraternities and artists. However, despite the abovementioned support for science in Australia, a significant proportion of the reporting population indicated that they do not feel very well-informed about science and scientific developments (45%); only 10% indicated that they do feel well informed. These results compared favourably with Eurobarometer Surveys and indicated that Australians are marginally more interested in the array of topics and felt similarly under-informed about scientific advancements compared to their European counterparts (Lamberts, Grant & Martin, 2010).

Questions relating to the value and contribution of science as well as questions assessing attitudinal aspects of the science-public relationship were also included in this section of the questionnaire, and here Australians generally indicated positive attitudes and appraisal of the contribution of scientists to society. A series of eight (8) separate questions were used to construct a scale resembling an index of promise and reservation. Individual questions used seven (7) response options, included a 5-point agreement scale, ranging from *strongly agree* to *strongly disagree*, including a *neutral* option as well as a *don't know* and *refusal* option. In the final construction of the index of promise and reservation, six (6) questions contained statements of general promise of science while two (2) questions contained statements of general reservation to areas of scientific advancement. Australians generally responded more frequently in agreement to statements of scientific promise, than they did to statements of scientific reservation, indicating a high sense of promise and general positive attitudes relating to science's impact on society. However, the majority of the respondents indicated ambivalence about the impact science may have on eradicating poverty as well as the ability of science to resolve any or all problems facing society. The above compared favourably with European results to similar questions. However, as before, Australians generally report more optimistically about the promise of science to society, compared with results of the Eurobarometer surveys (European Commission, 2013a; Lamberts, Grant & Martin, 2010).

The Australian 2010 survey also asked questions relating to the interaction of scientific advances and theory on the personal religious beliefs of respondents. While similar questions have been asked in other surveys, this topic has not received the attention in any other empirical work as that devoted to in the ANUpoll survey. Results from the survey does indicate that 30% of the sampled individuals reported belonging to no particular religious group; 69% of the total sample did however indicate that scientific views are often in conflict with their religious practices, while 26% indicated that their religious views are compatible with the scope and theory of current scientific work. On this measure, Australians presented a slightly different picture compared to results coming out of a similar series of questions from the United States of America, wherein only 55% of respondents indicated a conflict between their personal religious and scientific worldviews. However, there were minor differences in the manner in which the questions were presented in the two surveys. The ANUpoll also investigated areas of public understanding of policy as it relates to science and social issues. The majority of Australians (60%) indicated that the domestic science was on par with world scientific developments and achievements. However, in this section, Australians also indicated a less positive picture about government involvement in areas of science, public science policy and regulation associated with private sector scientific work in Australia. While Australians overwhelmingly agree that governments should rely more on scientific evidence in decision making (80%), a similar proportion further indicated that politicians should rely on 'sound' scientific advice and not information that has been interpreted by the media (Lamberts, Grant & Martin, 2010). While 31% of respondents agreed that private sector research is well regulated, 47% indicated a disagreement with the statement, but offered no further insight as to what regulations are required and to which end regulation would be beneficial. Yet in spite of those views, 77% of Australian respondents support continued government investment into scientific work to drive the progress of science in the country, which is higher than the percentage of Americans and Europeans who agreed with a similar statement in surveys of those territories (Lamberts, Grant & Martin, 2010).

The series of questions on science and climate change revealed that generally Australians remain divided and uncertain about climate research, with over 40% agreeing that there is limited consensus among scientists about climate and issues of global warming (Lamberts, Grant & Martin, 2010). Moreover, 34% of Australians further agree that there is a lot of disagreement between scientists with respect to the actual human influence on climate change since the mid-20th century. Results here again compared well to results from a similar American survey conducted by the Princeton Survey Research Centre, wherein a similar proportion of respondents agreed about the fact that the earth is warming, but differed by about 11 % with respect to their perception of agreement within the scientific fraternity on the actual impact human activities have had on climate change (47% USA, 59% Australia). In 2010, Griffith University Schools of Applied Psychology, Behavioural Basis of Health, Griffith Climate Change Response Program in conjunction with the National Climate Change Adaptation Research Facility conducted a dedicated survey entitled Public Perceptions, Understanding and Response to Climate Change and Natural Disasters in Australia

(Reser et al, 2012). This survey sampled 4 347 respondents on various issues of public understanding, perceptions and risk assessment of climate change. Respondents generally considered climate change and human impact on the environment to be a very serious problem, with 74% of respondents agreeing that climate change is currently happening in Australia. Further to this, 50% of respondents also reported that Australia is already dealing the impacts of climate change. The survey found that Australians knowledge of climate change was generally correlated with their associated concerns for the impacts of any potential climate shift (Reser et al, 2012). The study also found that belief / acceptance, risk appraisal, perceived responsibility, psychological adaptation to climate change, self-efficacy, climate change distress, trust, behavioural engagement, and perceived direct experience with climate change were also positively correlated with objective knowledge of climate change, illustrating the broad categories that may influence public understanding and engagement with general or specific issues that border the science-social spheres. While the survey results will not be discussed in great detail here as it only relates indirectly to the current chapter, the survey design will be revisited in the following chapter.

The above review of selected studies of *public understanding of science* and *scientific literacy* from more developed countries illustrates the approaches adopted in different countries. It also demonstrates the application of cross-national survey instruments in larger surveys such as PISA, TIMSS and ROSE. While some of these large cross-national surveys have been adopted in developing countries as well, they have been discussed here to allow greater focus on the distinctiveness that exists in some developing countries' studies of public understanding of science. In the next section we begin to discuss a selection of *public understanding of science* and *scientific literacy* studies from the developing world. Countries selected represent a mix of socio-geographical factors as well as studies of interest due to methodological uniqueness's that have proven valuable to the current study. The countries represented include China, Malaysia, India, Brazil and South Africa.

3.2 EMPIRICAL STUDIES FROM DEVELOPING COUNTRIES

3.2.1 Surveys of scientific literacy from the People's Republic of China

The People's Republic of China has, for the largest part of recorded human history, been the largest and most advanced trading and financial centre on earth (Dahlman, 2001). However, due to its protectionist strategies under both imperial and socialist rule, during the last 200 years China closed its doors to the outside world and, as a result, its economy stagnated due to under-industrialisation. Since the late 1970s, and following the opening of the Chinese economy to the global marketplace and the internal privatisation of former state-controlled industries, China has seen economic reform that in 2013 saw it become the largest Asian economy, with forecasts that it will become the largest economy in the world by 2020, overtaking the United States (World Bank, 2011).

At the turn of the 21st century, China again faced the challenge of adapting to a changing world as it had when it closed its doors to the industrial revolution. The emerging global knowledge economy represents the next chapter in the evolution of economic production, and to ensure that China meets the demands of this new challenge, the country began an internal process of gearing up toward meeting this challenge (Dahlman, 2001). In June 2002 the Chinese government ratified the *law on the popularisation of science and technology in China*, aimed at improving Chinese scientific literacy by 2020. The aim of this law, unique in the world at the time, was to ensure that science popularisation and scientific literacy efforts were directed toward national development, economic growth and long-term social progress for the Chinese state. In 2006 the Chinese government issued the *Outline of The Action Plan for Improving Scientific Literacy for All*, followed by *The Guiding Principles for Science Popularisation Capacity Building* and Strengthening in 2007 and the *Science Popularisation Infrastructure Plan* in 2008. The centralised approach in much of Chinese political reform strategies remains a legacy of the country's imperial and socialist history. However, the above milestone documents and laws, with their aim of promoting and developing scientific literacy, educational and socio-economic reform, have displayed some success in the immediate short-term as a direct result of targeted government focus on these issues (Sun, 2010). These various documents, under the Chinese *Law for The Popularisation of Science and Technology* take into account the varied demographic profile of its 1.4 billion citizens. These laws developed targeted actions for improving scientific literacy in four (4) main population groups, Youth, Farmers, Urban Middle Classes and the Political Elite/Public Servants. The targeted actions shared themes of enhanced educational approaches, supplementary science education and activities, access to scientific material and media sources as well as various training programs and scientific outreach initiatives. The aims of these various initiatives were to improve China's scientific literacy and equip Chinese citizens with the necessary skills to meaningfully participate socially, civically and economically in an evolving Chinese economy (Dahlman, 2001).

An important part of the Chinese science popularisation effort has been the Chinese Association for Science and Technology (CAST). Founded in 1958, following the amalgamation of two earlier organisations, CAST today represents 167 national academies of science and professional societies in China, with over 4 million members (Sun, 2010). As with many other countries in the world, sustained efforts and investment in scientific literacy projects have seen some improvement in overall levels of scientific literacy in China, with varying results within the different demographic clusters. China has participated in international surveys such as PISA and TIMSS (discussed above) and has displayed exceptional performance, with school learners achieving top scores in all measurement categories. It is however to be noted that results like these are not common for the broader Chinese population. While efforts by CAST and its partner organisations have shown some promising results, the rate of change is still very slow and China has made efforts to begin to accelerate change in the future (Hu & Peng, 2010). China is now in the second phase of the *Outline of The Action Plan for Improving Scientific Literacy for All*, wherein Phase 1, from 2006-2010, was designed to increase Chinese scientific literacy to that of developed countries in the 1980s. The second phase of the plan seeks to further increase Chinese public understanding of science and scientific literacy to match, by 2020, the goals set by developed countries at the beginning of the 21st century (Chen *et al*, 2009).

Interestingly, the concept of scientific literacy is defined slightly differently in China compared to the definitions encountered above. '…he or she possesses the ability to understand the necessary knowledge of science and technology, to know basic scientific methods, to keep thinking scientifically, to advocate scientific spirit, to use the above in making decisions in personal life and to participate in public affairs involving science and technology' (State Council of the People's Republic of China, 2006). Drawing on the earlier works of Shen (1975), Miller (1983), Shamos (1995) and The OECD-PISA (2000) definitions, a Chinese citizen is defined as being scientifically literate. While knowledge, attitude and application of scientific principles are important to the Chinese, they have also included elements that speak to a *scientific spirit*, a concept similarly shared in India that alludes to a general ideological position which binds all the elements of the previously mentioned attributes of scientific literacy (Wang, 2007 in Chen *et al*, 2009). Furthermore, the Chinese definition also takes into account the '…*necessary knowledge of science…'*, which alludes to a social and situational context for knowledge, attitude, ideology and behaviours by different segments of the population, as not all citizens require all forms of scientific literacy in every social context (Chen *et al*, 2009).

CAST has conducted six (6) surveys of scientific literacy in China, in 1990, 1994, 1996, 2001, 2003 and 2005. Those surveys employed methodologies applied elsewhere in the world and were based on the indicators previously established by Miller. Critics, like Li (2006, in Chen *et al,* 2009) argue that many of these indicators may not be suitable to the Chinese social context and have advocated for the development of socially applicable and relevant indicators for that country's context. Starting from the definition of scientific literacy adopted by CAST, appropriate measurement indicators, research instruments and research approaches were developed toward meaningful measurement. Scientific indicators were thus developed to measure the three (3) principle dimensions in the

Chinese definition: a) Scientific knowledge, b) Scientific awareness and c) scientific abilities (Chen *et al,* 2009). In conducting the research, each of these primary indicators is further broken down to sub-indicators that provide additional insight into primary indicator elements.

Primary Indicator	Secondary Indicator	Interpretation
Scientific Knowledge	Scientific concepts	Knowing and understanding basic science terms
	Scientific theories	Understanding basic scientific facts and principles
	Scientific processes	Understanding basic processes of science research and basic scientific methods
Scientific Awareness	Attitudes to science and technology	Appreciation of science
	Consciousness of using scientific knowledge and methods	Explaining observable phenomena using scientific rationales rather than supernatural or superstitious ideas
	Consciousness of testability	Insisting on testing ideas before believing them to be true
	Awareness of the impact of science on daily lives	The agreement or disagreement to socially impacting issues on the basis of some understanding of the issues at hand, rather than on prejudice
Scientific abilities	General abilities	Ability to use scientific knowledge in decision making and action
	Special abilities	Ability to conduct innovation activities

Table 3.6: Indicator system of Public Scientific Literacy in China, adapted from Chen et al, 2009

Table 3.6 above outlines the main and secondary indicators that were used to produce the 81 questionnaire items piloted for use in the revised survey series at CAST, and subsequently refined further within the larger project life cycle. Whilst the above indicators are incredibly valuable toward understanding Chinese scientific literacy profiles, opportunities and focus areas, the results of these initial pilot surveys have not been made public due to the metrics still being in a stage of development (Chen *et al*, 2009).

The first survey of Chinese public understanding of science and scientific literacy was conducted by CAST in 1990[18] (Zhang *et al*, 1993). Due to the large coverage area of mainland China as well as the size of the population, the survey employed a large number of fieldworkers to ensure that interviews were effectively and accurately completed. The sample design aimed at surveying 5 000 Chinese individuals, however yielded a final survey response of 4 523 responses from face-to-face interviews. The sample was designed to include a subset of all Chinese adults aged 18 years and older. As China consists of two major ethnic groups, both were included at the appropriate ratio so as to be representative of the population. The questionnaire developed for the survey adopted certain elements from the USA-NSF, the European Eurobarometer, the United Kingdom ONS surveys and the Japanese survey questionnaire items to ensure some degree of international comparison within the results. Significant alterations had to be implemented with respect to the language and item

[18] Despite more recent survey having been conducted, availability of full research reports in English is very limited; therefore the review focuses on the 1990 survey.

construction to account for the Chinese languages, culture and social contexts where fieldwork was conducted. Demographically, China differs considerably from developed world nations in that smaller proportions of the population have received middle and higher education and still fewer have any tertiary education. Furthermore 74% of the Chinese population still live in rural areas and are mostly involved in agricultural subsistence, thus removing them mostly from daily contact with science and technology. However, this is why China aimed to spread its influence through research, and thus the importance of these baseline measures.

China has a number of science information channels, from major investments in museum and science learning centres in the cities, to a large number of domestically published journals, magazines and news articles. National television and radio services have dedicated science programming aimed at a variety of demographic groups in China. The survey was thus conducted in a social climate of science prioritisation and generalised accessibility to material and science-related media, particularly for Chinese people in urban areas. The results of the survey indicate that television, radio and print material respectively remain the major sources of scientific information for Chinese nationals. The three least selected options for sources of scientific information - *public libraries*, *science centres* and *museums* - were rated as not being very popular information sources for the majority of respondents in the survey. In comparisons with data from the USA NSF survey of the same year, more Chinese (36%) than Americans (20%) reported television as the primary source of scientific information. Interestingly, however, with respect to the aforementioned three least-popular information sources in China, significantly more Americans reported these as more important information sources, particularly *public library* resources, where 51% of Americans visited public libraries three or more times a week, compared to only 7% of Chinese.

Results of questions relating to understandings of scientific terms and methods were assessed through a battery of questions that asked both general questions and questions on specific fields of science or rooted in specific scientific concepts (Zhang *et al*, 1993). Questions seeking to probe the understanding of scientific terms asked respondents their level of understanding with regard to three (3) terms: *Molecule, DNA* and *Computer software*. The majority of Chinese citizens either did not respond to each of the three questions or provided an incorrect answer, and only 7% provided correct answers to demonstrate an accurate understanding of these terms. In general, male respondents showed a better understating of the three scientific concepts compared to female respondents, while similarly, younger respondents also reported more frequent correct answers compared to older respondents. With respect to international comparisons, American and British surveys report similarly poor understandings of scientific concepts; however the rate of response is not as low as demonstrated within the Chinese survey. The understanding of scientific methods and processes were also investigated in this survey and the results indicate that generally Chinese respondents do not have a clear understanding of what it means to study something scientifically. The results indicate that only 7% have a clear understanding, while 39% demonstrate a general sense of what it means to *study something scientifically* (Zhang *et al*, 1993).

Questions relating to specific fields of science investigated public knowledge of Physics, Astronomy, Human Origins and Health with a series of *true / false / don't know* questions. Consequently only 4% of respondents answered all questions about physics correctly, 50% of respondents answered all or most of the questions relating to Astronomy correctly. The majority of respondents answered the questions correctly relating to human origins and evolution, while only 2% were able to answer all questions relating to areas of Health (Zhang *et al*, 1993). For all the questions relating to specific fields of science and public understanding, results indicate that males generally perform better than females, younger people better than older respondents and Chinese generally answered fewer questions correctly compared to their counterparts in the USA and the UK (Zhang *et al*, 1993). The 1990 survey furthermore contained an index of *promise and reservation* assessing attitudes in relation to the social impact of science and technology on Chinese society. In the Chinese survey, 78% of respondents report that the positive impacts of science on society have outweighed any negative impacts that may result from science and technological work, while only 1% indicated the reverse sentiment. Furthermore, 82%, 71% and 41% respectively agree with the statements science *is making life healthier*, *science will make work more interesting* and *government should support basic research* UK (Zhang *et al*, 1993). These positive appraisals of the impacts of science and technology on society is shared by the majority of respondents in the survey, many of whom see much future promise in the contribution of science to society.

While these data points relate to the 1990 CAST survey, more recent surveys similarly report low levels of scientific literacy in China, and in certain cases some sub-indicators are today reporting even lower levels of scientific literacy than in the 1990 survey (Sun, 2010). In the 2009 survey, though detailed reports are not available, media reports from the survey launch at the 12th CAST annual meeting in 2010 report that recorded only 3.27% of those surveyed could be considered scientifically literate - a significant increase from 2.25 % in 2007 and 1.98% in 2003 (Hu and Peng, 2010). China has begun emerging as an economic force and has proven that the might of its growing economy can exert influence far beyond its borders (Pronina, 2013). Growing the human resource capabilities and outputs in the region will become increasingly important as the society relies more on science and technology solutions for economic production, social services and effective governance. Through the prioritisation of science and technology in its national system of innovation, China has already started a process of long-term social, financial and developmental investment to ensure the goals and targets of the *Outline of The Action Plan for Improving Scientific Literacy for All* are met. Change has arrived very slowly, however, and Chinese researchers have begun challenging the status quo with respect to scientific literacy and public understanding of science measurement in China. The imported measures of scientific literacy used elsewhere in the world have proven not to be useful for measurement in the Chinese context, and work has begun in redeveloping more appropriate measures. By redefining scientific literacy within the varied Chinese contexts and developing measurement techniques that meet the different social and cultural milieu extant in those contexts, China has provided key lessons to be gleaned that hold promise for the application of these approaches in other developing world settings.

3.2.2 Malaysian surveys of scientific literacy

Malaysia is a South East Asian nation, consisting of 13 states on two (2) land masses: Peninsular Malaysia and East-Malaysia separated by the South China Sea. A multi-ethnic nation with a population of just over 30 million citizens, like so many countries in this region, it has a colonial history as a British protectorate until 1957. As a result of this, much of the political, legal and educational spheres of service in Malaysia are modelled on the British system. Consequently, Malaysia boasts among the best educational systems in the region (Hock, 2007, MASTIC, 1998). Malaysia has built a formidable economy since independence, demonstrating strong positive economic growth, traditionally fuelled by its natural resources, but more recently sectors such as space technology, tourism, medicine, science & technology and particularly biotechnology has seen tremendous growth (MABIC, 2014). The country has a well-established schooling system, offering multilingual and free compulsory primary school, and secondary as well as tertiary schooling. With a major focus on education, Malaysia has 37 private universities, 20 university colleges, 7 foreign universities as well as 414 private colleges (Maierbrugger, 2013). Having recognised the impact of science and technology on society, the Malaysian government has invested considerably in education toward boosting economic productivity, competitiveness and standards of living (MASTIC, 1998).

Since 1973 Malaysia has had a government ministry of science and technology, under various names; however in 2004 this ministry was officially renamed to the Ministry of Science, Technology and Innovation (MOSTI) toward leading the national policies for S&T, ICT, biotechnology, industrial innovation and sea & space science (MOSTI, 2014). MOSTI operates under a mission statement of nine (9) strategic thrusts relating to science technology and innovation, human resources, R&D

investment, social transformation, collaboration, and public involvement in STI initiatives. In 1992, MOSTI established the Malaysian Science and Technology Information Centre (MASTIC) as a result of the Industrial Technology Development Plan to coordinate a strategic STI research, information and support to government, the private sector and the general public on matters of science, technology and innovation. As part of its science, technology and innovation indicator development initiatives, MASTIC conducts a number of research projects toward the development of an STI indicators report. These indicators draw information from various surveys that include R&D surveys, Innovation surveys, Bibliometric studies, STI facility audits as well as surveys of public awareness of science and technology in Malaysia.

Malaysia has in the past participated in a number of international surveys of public understanding of science and scientific literacy. More recently Malaysia has participated in the OECD-PISA surveys since 2009 and again in 2012. On average, Malaysian learners scored lower than the OECD average on almost every category of the PISA assessment. Scores on scientific literacy, in particular, were lower than the OECD average of 501, with Malaysians scoring 420 points on average (OECD, 2014). Interestingly in Malaysia, female learners performed better on scientific literacy measures compared to male learners, contrary, though not exclusively so, to what had previously been observed in other countries participating in the PISA assessment. In the 2012 PISA assessment, Malaysia ranked 52nd on the 64 countries participating in the 2012 survey, outperforming only Indonesia within the Asian region (OECD, 2014).

The first nationally representative survey of public awareness of science and technology in Malaysia was conducted in 1996 and has since been conducted biennially with the most recently available report being for the 2008 survey. To enable international comparison, Malaysia adopted definitional characteristics and questionnaire items similar to that of the NSF in the USA Science and Engineering Indicators surveys, assessing public knowledge and interest in science, attitudes toward science, understanding of scientific concepts and procedures as well as data about scientific information sources among Malaysians. The survey sample is designed to survey 5000 respondents, taking into account demographic profiles from across Malaysia's many states and the multi-ethnicities within the population. The questionnaire consisted of both open- and closed-ended questions, using similar questionnaires from the USA, the UK and Europe as reference. The final questionnaire consisted of forty-three (43) questions and was divided into eight (8) sections: *issues of science and technology, media, science exhibitions, S&T knowledge, benefits of S&T research, general understanding toward S&T, involvement with public policy issue regarding S&T* and *demographic profile of respondents.* The survey used face-to-face interviews by groups of fieldworkers within six (6) demarcated fieldwork zones, while ensuring national representivity in the end sample (MASTIC, 1998).

In general, Malaysian citizens were moderately interested in S&T issues, indicating the highest interest in ICT innovations, new technologies and, despite waning interest since the 1998 survey, environmental issues were still highly rated by respondents. As expected, urban respondents expressed higher interest in issues of science and technology (S&T) compared to rural residents. However, the 2008 report clearly notes the trend of increasing interest in issues of S&T among the rural population, demonstrating a positive change in the profile of the population interested in S&T issues (MASTIC, 2008). Compared to the 1998 and the 2006 survey, the results of the 2008 survey indicates a general decrease in Malaysians self-reported knowledge of S&T. While this was not universal to all aspects of science, it did have a specific commonality of natural science focus, including nuclear power, the latest scientific breakthroughs and research (MASTIC, 2008). While many responses from Malaysians seem to be affected by highest educational achievement level unlike in more developed countries, the influence of location (rural or urban) and gender is not as noticeable as a direct result of efforts toward improving the outcomes within this indicator in Malaysia.

The 2008 questionnaire contained eight (8) items that looked at attitudinal aspects of the science/ public relationship (MASTIC, 2008). Attitudes toward S&T in Malaysia have changed significantly over the period 1996 to 2008. In 1998, 43.8% of respondents agreed that science delivers a more positive influence to society than negative; however, in the 2008 survey this number increased to 73.8% of the population, indicating an upward trend in certain aspects of the Malaysian public's attitudes to science. In a follow-up question, seven (7) aspects of life were isolated and assessed in relation to the perceived impact science and technology had on each one. The majority of respondents reported that science and technology in Malaysia had a positive effect on standards of living (77%), public health (71.1%), cost of living (56.0%), working conditions (67%), individual enjoyment of life (59.9%) and the environment (54.1%). These results were echoed in trend data from previous surveys where similar response patterns were observed, indicating a consistent and increasing positive reception by the Malaysian public. As with developed countries, correlations between education and age in relation to attitudes toward science were found to be positive between education and age in relation to attitudes toward science (MASTIC, 2008). Similarly, more urban respondents were inclined to agree with positive statements about science than their rural counterparts; however the difference was very minor and observed to be decreasing annually within Malaysian society. Unlike the case in developed countries, gender differences were not pronounced in terms of public understanding of science and no differences were reported across the varying ethnic groups in Malaysia.

As in other surveys of this nature, scientific understanding of particular issues was dependent on the subject matter being discussed. By asking a series of 15 true/false/don't know questions, respondents were assessed with respect to their level of understanding of scientific concepts. On the more basic scientific concepts (e.g.: smoking causes lung cancer or the earth revolves around the sun), generally respondents scored very well. However, when it came to more complex questions that required some special knowledge rather than general school-level science education (e.g.: *Antibiotics kill viruses as well as bacteria* or *all radioactivity is man-made*), many respondents were unable to provide the correct response to the question (MASTIC, 2008). The questionnaire also included two similarly designed items; however, with subject matter relating to more publically disputed scientific theories (e.g. *the universe began with a huge explosion* and *Human beings as we know them today developed from earlier species of animals*). Results indicate that since much of the information relating to these questions are socially questioned in Malaysia; there was a fair degree of ambivalence in responses, with just over 50% agreeing to the statements posed to respondents.

Data on the most popular sources of scientific information was also collected in the survey; as in other nations, television (82.4%) and newspapers (62.1%) were the most important sources of public science information for Malaysians in 2008. The internet was cited by only 24.8% of respondents and recorded the least number of positive responses. Furthermore, for all of the above categories - television, newspapers, internet and radio - a decline in reported sources of science information was recorded, which researchers have attributed to questionnaire changes between the current and previous round of surveys (MASTIC, 2008). Whilst a smaller segment of the respondents report visits to science parks, museums and similar facilities, the most popular of these were zoos (30%), museums (29.9%) and science parks (29.7%).

Malaysia performs well compared to other developing countries, and has ranked above India in scientific literacy and public understanding of science measurement rankings (MASTIC, 2008). However, when compared to many developed world countries, Malaysia remains below the levels recorded in the USA, Europe and the UK, mostly linked to social and cultural differences in the various regions in Malaysia. While basic scientific knowledge appears to be well understood among respondents, more complex or debated scientific theories (e.g. human evolution) continue to demonstrate lower levels of general public understanding from within the Malaysian public (17%).

3.2.3 Public Understanding and Attitudes to Science in India

India is a country steeped in history, with the earliest civilisations dating back some 55 000 years (Petraglia and Allchin, 2007). Since before the Christian era (BCE reference period) the region has played host to varied cultural, religious and military revolutions that have influenced and shaped Indian society into the dynamic democracy it is today. Throughout this long, and at times brutal history, India has constantly been involved in innovation, having developed drainage and sewerage systems, early crop cultivation and agrarian technologies, technical standardisation for measurement, transportation hubs, hydrology , metallurgy, astronomy, construction, healthcare, mathematics and military strategy (Petraglia and Allchin, 2007). Following the Mughal Period (1526–1857) and the colonialist period under the *British Raj* (1858–1947) India achieved independence in 1947 and set its sights toward building its national image, as well as its economy, educational institutions and healthcare system. Even before Independence, the Indian liberation movement spearheaded the movement for social and political empowerment through calling for the advancement of education and industrialisation (Raza and Singh, 2008). The beginning of the 19th century India saw the birth of the *Association for the Advancement of Scientific and Industrial Education of Indians,* which had, among its goals a strategy of sending talented young Indians to industrialised nations to receive their education in various fields of science and technology (NPTEL, 2013). Similarly, under the leadership of Jawaharlal Nehru - the first prime minister of an independent India - the ideals of the Indian liberation movement were clearly understood to rely on the acceptance of scientific ideas toward industrialisation and modernisation of the new nation state (Raza and Singh, 2008). Nehru understood that the growth of a *scientific temper* in India would be indicated by the extent to which the population started incorporating scientific principles into their daily lives and work, toward problem solving and increased productivity. Venkateswaran (2013) records Nehru’s words on science: *‘It is science alone, that can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening of custom and tradition, of vast resources running to waste, or a rich country inhabited by starving poor... Who indeed could afford to ignore science today? At every turn we have to seek its aid... The future belongs to science and those who make friends with it.’*

Nehru realised that this required the technical human resources to drive the modernisation of India, which heralded the notion of science communication in India (Venkateswaran, 2013). In 1953, Nehru initiated the *Vigyan Mandir* projects (translation: *Knowledge Temples*) wherein community centres were set up to facilitate learning and the dissemination of scientific ideas directed at agriculture, health, sanitation and related issues in 125 regions across India.

During the latter part of the 1950s and the early 1960s, various new books and science-related radio broadcasts started appearing in India, driving the notions of a *scientific temperament* and *a broad scientific outlook* in a bid to communicate modern scientific ideas to the population. However, this highlighted a peculiarity within the Indian population, as many of the scientific terms and concepts did not find a natural translation into the many dialects and languages on the subcontinent (Raza and Singh, 2008). This started a process whereby scientific terms were being coined in the various languages and dialects. Another common feature of the time was the incorporation of several anglicised terms into the teaching and learning strategies of the time. At this very early stage, the State recognised that nation building relied heavily on the adoption of science and technology which would facilitate modernisation of the economy, the people, productivity and ultimately the international competitiveness of the nation. Science and technology were also seen as valuable political tools for raising the Indian population's awareness and consciousness during a politically unstable time for the new nation (NPTEL, 2013). By the 1970s, efforts to organise science communicators led to the formation of the Kerala Sastra Sahitya Parishad (KSSP) in an bid to popularise and disseminate scientific beliefs and awareness in the many rural parts of India. The KSSP was instrumental in organising the A*ll India Peoples Science Movement*, which was influential in developing the grassroots science popularisation efforts called *Science Jhatas* (translation: *processions*). These science processions visited many towns and villages in India, hosting lectures in local languages and dialects as an early effort to create a *scientific temper* within the population. Due to the fact that much of the more than one billion Indians (at the time) had not received high levels of formal education, these *Science Jhatas* proved to be invaluable educational resources for the many to aid them in their productive, personal and social lives. The value of these were to be tested following the 1984 Bhopal Gas Tragedy where, after a gas leak at a chemical factory, 3 000 people died instantly and more than 16 000 lives were ultimately lost due to this industrial accident (BMHRC, 2008). Public outrage in India was tremendous at the time, with many violent protests unfolding in response to people demanding accountability for the tragedy. During this time these Science *Jhatas e*xposed millions of people to the scientific and technological processes as well as the risks of having chemical plants in densely populated areas, and provided perspective as well as greater understanding, thereby assisting in minimising the general sense of fear within the immediate populations (Raza and Singh, 2008).

In 1989, the Indian National Institute of Science, Technology & Development Studies (NISTaDS) initiated the first projects devoted to studying the *public attitudes and understanding of science* (PAUS) in India. Many of the existing studies and measurement indices of the time relied on the established Western notions of *scientific literacy* and the *public understanding of science* measurement techniques. The NISTaDS experts believed this to be inadequate to study the Indian population's understanding of science as a result of the cultural and linguistic variations within the population as well as its contrast in relation to modern industrialised countries where these indices and measurement approaches were developed (Rose, 1991 in Raza and Singh, 2008). The researchers from NISTaDS formulated a study that was to be conducted in 1989 at the *Kumbh Mela* festival, which attracted almost 50 million religious devotees to the town of Allahabad. The reason for selecting this festival was clearly to survey as many people as possible from all over India, given the limited resources at the disposal of the research team.

As an exploratory effort to establish a reliable measurement technique that would be applicable to the Indian context, the initial Kumbh Mela studies aimed to achieve four goals: 1) identifying the areas of knowledge that were relevant, 2) selecting questions for use in the research, 3) identifying the model answers for the questions and 4) identifying the factors that influence people's understanding of science (Singh and Raza, 2012). In identifying the primary knowledge areas for the development of a survey of Indian public attitudes and understanding of science, the surveys focused on areas of most importance to the majority of Indian citizens, namely a) astronomy and cosmology, geography and climate, agriculture as well as health and hygiene. These areas provided the required local relevance of knowledge areas as well as a fair degree of international comparability, as areas of hygiene; health; cosmology and astronomy have all been included in Western surveys of scientific literacy and the public understanding of science. Thus the question sets were developed within these four (4) areas. The final questionnaires contained, on average, twenty-six (26) questions covering the above-mentioned knowledge areas, and elicited nearly 16 000 responses (Raza and Singh, 2008). Response options were divided into four (4) possible types, including 1) scientifically correct answers, 2) naturalist/or secular responses – but scientifically incorrect, 3) turning to the divine for the explanation and 4) *don't know* responses. In particular, Raza and Singh (2008) note that the *don't know* responses provide an indication of the *cultural distance* between the respondents' lived experience and knowledge and, the construct being investigated.

The Kumbh Mela studies administered during the *Kumbh* and *Ardh Kumbh Mela* festivals at Allahabad in 1995, 2001 and 2007 were used to develop a cultural distance model to explain respondents' responses to various questions about science and technology. The data indicated that as the complexity of the subject matter increased, so too did the number of scientifically correct responses decrease among the sample group. Questions regarding the shape of the earth yielded many more correct answers compared to more complex questions relating to evolution and other similar complex knowledge areas (Raza and Singh, 2008). Cultural distance did appear to vary between rural and urban respondents and was also impacted by educational level, employment status and profession. The Kumbh Mela studies indicate that between the years 1989, 2001 and 2007 - across all knowledge areas - the number of scientifically correct responses has been increasing, while the number of scientifically incorrect responses has generally been decreasing. Similarly, the number of *don't know* responses have also decreased across the period. Although in the agricultural knowledge area it did show some increase during the 2007 round of the survey (Raza and Singh, 2008). The use of the '*don't know'* response option was significantly higher among the urban respondents than among rural ones. This highlighted the finding that the migratory patterns of the Indian population, from the rural villages to more urbanised areas, as well as the rapid urbanisation of areas previously on the rural-urban fringe, has led to a loss of traditional knowledge factors while at the same time being sensitive to cultural and education factors. This suggests that the migratory patterns and urbanisation in India, leading to urbanised socialisation and education might not be sufficient to increase scientific literacy and scientific temper in this developing world context (Raza, Singh & Dutt; 1995). The authors of this study also believe that the cultural transition from the rural to the urban centres has left younger generations in 'a state of transition' that has not yet yielded adequate exposure to have generated a suitable cultural assimilation for the development of a unified public understanding of science (Raza, Singh & Dutt; 1995).

Whilst the concept of the *public attitude and understating of science* in India has been highlighted as culturally different from that of Western constructions, requiring different measurement techniques, it will inevitably have to be related to previously discussed notions of scientific literacy. Due to a lack of reliable and internationally comparable data, in 2004 the Indian National Council of Applied Economic Research (NCAER) conducted the National Science Survey. Investigating three (3) major areas of the public-science edifice, the study explored the status of science and engineering education, the utilisation pattern of human resource and public attitude towards science and technology in India. The survey covered both urban and rural centres, yielding a final sample 30 000 respondents in face-to-face interviews (Shukla, 2005). While the report details results from all three sections, the review below will only cover results pertaining to the chapter on *Public Attitude towards Science and Technology*.

Results from the 2004 survey demonstrate an evolving system of science and educational exposure, with many positive indicators for public understanding of science research and policy. Public understanding of scientific concepts was assessed through a series (twelve) 12 questions that covered a range of scientific concepts and required varying levels of background knowledge and levels of conceptual complexity. These questions were accompanied by three response options: *true, false* and *don't know,* in order to best facilitate answers and data capture. Questions ranged from elementary concepts such as 't*he centre of the earth is very hot'* and *'the oxygen we breathe comes from plants'* to more complex subjects dealing with human evolution & genetics, agricultural sciences and health. Overall, 57% of respondents answered these questions correctly. However variances were noted for the level of education as well as the domicile location of the respondent. Similarly, with more complex concepts, a higher incidence of incorrect or *don't know* answers were selected, which is particularly notable when viewed against prior educational achievement and income group (Shukla, 2005). What was interesting was that locally relevant knowledge that relied on traditional knowledge systems relating to the environment and natural phenomena were better understood among the rural samples, as a result of daily relevance to living conditions. Similar relationships to those in industrialised countries were highlighted, where younger participants and males generally answered more questions correctly compared to their senior and or female counterparts.

Public interest in an array of social issues was assessed by using a 3-point scale of reported interest in issues (*Interested, not interested, no opinion*). Respondents were presented with fourteen (14) broad areas of public policy issues and were asked to select a level of interest for each of the categories. Despite low income and education levels in India, the majority of respondents reported high interest in many of the issues listed. Shukla (2005) reports that in certain knowledge areas, the levels of scientific interest among Indians surveyed are higher than that of developed countries such as the USA. This is particularly related to health and environmental issues that are greatly influenced by traditional knowledge systems that continue to make these knowledge areas relevant on a daily basis. As expected, the level of interest in particular public issues was also related to the location, age and the relevance of the issues to the daily activities of the individuals. Highlighted again in this question series is the idea of cultural distance, where issues that are more relevant attract a greater indication of interest (poverty and gender issues) than issues that are not as relevant, such as *space exploration*. Juxtaposed to the reported level of interest in scientific and public issues, the level of 'informedness' was also assessed for the same set of 14 *interest* areas, using a similar 3-point scale of 'informedness'. Generally the data indicates that the people who reported interest in particular issues similarly reported 'informedness' related to those issues - albeit at a slightly lower level (Shukla, 2005). As a departure from the previous correlations between age, gender and domicile location, levels of informedness were more complex in their nature and tended to differ by subject area.

The questionnaire included 12 questions relating to Indians' *attitudes toward natural phenomena*, eliciting responses that differed in terms of their content. These could be categorised into four (4) types: a) scientifically incorrect, b) scientifically incorrect, but based in scientific methods, c) attribution to the Divine and d) don't know. Here it was found that *levels of income* and *education* exhibited particular influence on the responses selected. Whilst the majority of both rural and urban, male and female as well as old and young individuals reported correct answers to questions relating to the *rotundity of the earth*, *gravitation* and *natural phenomenon*, differences were observed with respect to education and income levels (Shukla, 2005). Similarly, an average of 10% of respondents in both rural and urban centres continue to attribute many natural phenomena to the *Divine*, which, in a traditional population, where the lines between natural and the divine often are blurred and inseparable is to be expected (see accounts of Hindu Goddess, *Saraswati*[19]). *Knowledge and informedness of technologies* were assessed along four (4) technology categories: *Agriculture, Household/Domestic, Communications* and *Health*. Questions were constructed around the technologies prevalent within in each technology class, and a level of informedness per technology class was derived (Shukla, 2005). With the exception of *communications* technologies (due to low penetration), the majority of respondents indicated a moderate or high level of informedness in each technology class. Actual usage of technologies in each technology class was also reported, but this will not be discussed further in this section.

The sources of scientific information for Indians were assessed by providing seven (7) information sources as well as a category grouped as *other*. As in many developed and developing countries, television remains the primary source of scientific information for the Indian population, with 57% reporting this as the primary category. This was almost five (5) times higher than the next categories of *radio* and *newspapers, which* were reported approximately 10% of the time. This remained true for rural populations, where almost 50% of respondents indicated *television* over *radio* and *newspapers,* likely due to the higher rates of illiteracy in rural areas. Interestingly, new media, such as the internet and social media information sources were not assessed in this question, which may be as a result of the limited internet penetration across rural India. The majority of respondents indicated that scientific information is most often accessed at *home* or at a *neighbour's house*, while *public access* and *workplace* information access was reported in only a small minority of cases (Shukla, 2005). There were no significant variations in these patterns of information access location when correlated to other individual factors such as age, gender, income, education or domicile location, except with relation to internet access. As a result of limited private internet infrastructure

[19] Hindu goddess of knowledge, music, arts, wisdom and nature which in some parts of India, both rural and urban, make separating scientifically correct explanations of natural phenomena from divine explanations difficult.

in certain Indian areas, the majority of respondents report public spaces and work as the primary internet access point, with over 70% of rural and 40% of urban respondents indicating poor or no internet access (Shukla, 2005). The majority of respondents indicated a higher level of confidence in television and radio based scientific information, compared to the very low levels of confidence reported in local/political leaders. However, with the exception of *television*, between 25% and 30% of respondents did select the *do not know* category. Using the various responses to the questions discussed above, Shukla and colleagues continued to categorise respondents into categories of *attentiveness to science communication*. Attentiveness was categorised through a combination of *interest, informedness and active information-seeking behaviour* (discussed above). The 2004 India Science report classifies approximately 19% of Indians as *attentive* to science communication, with a further 11% classified as *interested* (Shukla, 2005). This varied with the earlier mentioned factors, including domicile location, education as well as income levels of respondents. In addition to this, a large number of respondents were neither categorised into *attentive* or *interested* categories and instead were included in a *residual* classification (Shukla, 2005).

Ever since its independence from its colonial rulers, India has a large and active community of scientists working on issues of the public understanding of science and scientific literacy. Many science councils have dedicated communication sections and concerted efforts have been made in recent years to use all traditional and modern communications approaches in a more synchronised manner in its efforts to reach its 1.3 billion people. The recognition that imported measurement and educational techniques in this particular area is less than ideal for the Indian, and indeed the developing world context, continues to drive renewed research efforts within the Indian research community. Work continues toward understanding the concepts of cultural distance as well as the development of measures and indicators to best measure the Indian public understanding and attitudes toward science and technology.

3.2.4 Public Understanding of Science and Scientific Literacy Research in South Africa

South Africa as a country has seen a number of social, political and economic changes in its recorded history. As discussed in chapter 1, with the arrival of the various colonial powers in the Cape during the mid-1600s, the face of South African society was forever changed by institutionalised inequality and on numerous occasions resulted in violent conflict between the various powers that sought to claim control of this southernmost tip of Africa. Whilst *separate development* and *minority control* were not new concepts to South Africa and its population, the institutionalisation of apartheid in 1948 and the numerous state laws that enforced this ideology following that period steered South Africa further in the direction of separate development and the eventual resistance to the brutality of the apartheid regime. However, as a result of more than 50 years of oppression and separate development, the vast majority of the South African population was denied access to basic services, adequate healthcare and quality education, resulting in a large portion of the population lacking in the skills required for developing industry and growing the South Africa economy[20].

With the dawn of democracy in South Africa in 1994, key focus areas for the new government included improved service delivery, access to housing, job creation, economic development and education for all South Africans - particularly those under-serviced by the apartheid government (Noble *et al*, 2008). In the 20 years since the end of apartheid, there have been a number of government initiatives and policy revisions aimed at redressing the inequalities created by the apartheid system as well as its legacy impacts that have persisted to the present day. Despite these, many efforts by government and non-governmental-organisations toward social change, economic reform and industrial development have not reached expected levels in post-apartheid South Africa (Noble *et al*, 2008). While there have been improvements in selected areas, a large proportion of the population still live in situations of dire poverty, access to essential health and social services remain constrained and economic performance has been slow with respect to the evolving continental and global macro-economic environments. Public scientific literacy and an enhanced public understanding of science have been heralded as key toward long-term social and economic change in South Africa (Pouris, 1991, 1993; Blankley and Arnold, 2001; Reddy *et al*, 2009).

A critical element required toward developing scientific literacy and a better public understanding of science in South Africa has been the promotion of increased quality of both formal and informal education structures (Laugksch, 1996). The ultimate goal of enhanced educational and social learning programmes have been aimed at developing the South African labour force toward enhanced and increased industrialisation, economic development and effective citizenship (Pouris, 1991). Laugksch outlines the three (3) key arguments for the promotion of scientific literacy in South Africa: 1) economic benefit, 2) personal decision making applications and 3) the promotion of effective democracy and citizenship toward nation building (Laugksch, 2000). It is without doubt that South Africa has made some progress in the 20 years since the end of apartheid; however many have contended that progress has been too slow; and much of the legacy impacts are still being perpetuated, despite the first generation of 'born-frees[21]' now entering the workforce. For South Africa to realise its developmental, social and economic goals, concerted efforts must be made in a

[20] It must be noted that there were a number of outstanding academics, social and business leaders emerging from the non-white populations in South Africa during this time. However relative to the general population these were still, and currently remain the minority in South Africa.
[21] Referring to South African citizens born in and following 1994

number of areas, and certainly a human resource base, equipped with the requisite knowledge and skills for facing those challenges, is paramount to any envisaged future success in this regard.

The genesis of the study of the public understanding of science and scientific literacy in South Africa started later than many of the countries previously discussed. Laugksch (1996) claims that the first mention of *scientific literacy* in South African academia was following the 1978 South African Association of Teachers of Physical Science (SAATPS) workshop discussing how science education in South Africa could be improved. However, it was not until the mid-1980s that dedicated research in the area of scientific literacy was conducted. Laugksch outlines two major areas of focus for scientific literacy research in South Africa. The first focus was aimed at enhancing teaching and learning through the study of informal science education and its impacts on formal science classes and how this combination impacted the scientific literacy of learners (see Maarschalk and Strauss, 1992 in Laugksch, 1996). The second focus area for scientific literacy research in South Africa emerged in the latter part of the 1980s where surveys of scientific literacy and public understanding of science began to emerge on the research landscape. Many of these early surveys adopted the approaches of Miller, Durant, Evans and the contemporary vanguards of the scientific literacy and public understanding movement in Europe and the USA. However, it must be noted that under apartheid, and at the height of the democratic struggle in South Africa, access by research teams to townships, and non-white populations was difficult at the best of times and due to this, many of these early studies focused on a single or limited number of demographic groups. While a nationally representative sample of South African's public understandings of science has yet to be conducted[22], Table 3.8 outlines a number of surveys on public understanding of science and scientific literacy in South Africa, since 1991. In order to develop an appreciation of public understanding of science research in South Africa, a selection of these studies will be presented in this section in order to understand the areas previously researched as well as the instruments used and approaches followed. As some of these surveys had a specific scientific focus or limited demographic inclusion, it becomes difficult to meaningfully compare their results. However, where possible, domestic and international comparisons will be presented as opportunities arise, and in chronological order.

3.2.4.1 Surveys conducted from 1990 to 2000

Early attempts at replicating scientific literacy surveys using imported survey questions and approaches from the *USA-NSF* and *Eurobarometer* surveys were conducted by the Foundation for Education, Science and Technology (FEST) by Pouris in 1991 and again in 1993. In the 1991 study,

[22] I note the work of Blankley and Arnold, 2001 and that of the HSRC surveys that have attempted this. However, many of these had limited areas of focus for scientific literacy or limited applicability in contemporary post-apartheid South Africa.

Pouris examined *public understanding and appreciation of science among* [a selected group of] *South Africans*. The study surveyed 1 300 respondents, 800 white female and 500 white male in six (6) urban suburbs in cities across South Africa. The fieldwork was conducted by a research company during January 1991, using face-to face interviews and a national field force of trained interviewers. Survey questionnaires resembling *NSF* and *Eurobarometer*-type questions, were developed asking respondents about areas relating to physical science, earth science, human evolution, attitudes toward astrology, public perceptions relating the impacts of science in everyday life as well as respondent demographic information (Pouris, 1991). Seven questions assessing scientific factual knowledge were asked, with topics ranging in complexity from *hot air rises* and *the centre of the earth is very hot* to more complex questions relating to the scale of matter and laser technology. On knowledge measures, generally, South Africans in 1991 compared favourably to UK and USA respondents on a similar question set. A notable difference emerged with respect to more complex questions relating to lasers and the scale of matter where South Africans displayed less factual awareness relating to those areas. Within the South African results, males generally performed better than female respondents, but only marginally. In addition, a very small number of respondents reported under the *don't know* response option, with the exception of the earlier mentioned, more complex categories wherein a marked increase in *don't know* responses were recorded. Language was found to differentiate the sample, with English speakers performing better than their Afrikaans counterparts. However, it is not stated if the questionnaire was available in both languages and if this may have impacted these finding. Similarly, and counter to expectations, older respondents generally performed better than younger respondents. Questions relating to the public beliefs about areas such as *human evolution* and *astrology* indicated that South Africans in 1991 held a limited understanding of these concepts compared to their foreign counterparts in the USA and the UK. However, on a question relating to humanity's dependence on science rather than faith, more South Africans agreed with this statement (71%) than did Americans (44%) or British (51%) (Pouris, 1991). On question-set assessing public attitudes toward science, South African respondents report a general positive attitude and understanding of science. However they also express some reservation about the impact of scientific advances on daily life. Interestingly, more South Africans report an appreciation of the benefits of science over any potential harmful effects (59%) compared to similar results for the USA (44%).

As an interesting finding from his 1991 work, Pouris noted the higher rates of scientific literacy in older respondents compared to those of younger participants and, in his 1993 study, shifted his focus to *South African teenagers' understanding and appreciation of science*. A total sample of 800 teenagers were accessed in the 1993 study, with respondents selected from the major urban centres across South Africa, as in the 1991 study. Face-to-face interviews were conducted with 400 Black[23] and 400 White respondents of both genders between 13 and 20 years old (Pouris, 1993). In addition to the collection of demographic detail, many of the questions from the 1991 study informed the development of the 1993 questionnaire. The 1993 study found that white teenagers (of both genders) performed better than their black contemporaries on measures of factual scientific knowledge. As in the 1991 study, English speaking respondents outperformed any other language group in the study. Among black respondents, results were also stratified according to language, where it was found that Sotho speakers generally performed better than those speaking Zulu, Tswana, and Xhosa[24] (Pouris, 1993). Across racial and language groups, males performed better than female respondents, however the difference between the genders was greater among the white groups than among non-white groups. With respect to questions about beliefs and attitudes toward science, Afrikaans respondents generally provided a greater number of negative responses than both other white and non-white respondents. Conversely English speaking respondents most frequently expressed a lower positive attitude toward scientific advances and its impact on daily life (Pouris, 1993). Despite the impacts of apartheid on access to resources and education in 1993, black respondents reported being more optimistic about science and the advances that impact on daily life.

The Human Sciences Research Council (HSRC) has since 1968 been involved in South African human and social policy-orientated research and has conducted numerous studies in the different focus areas, from democracy and governance, social determinants of health, social cohesion and science and technology-focused research activities. In 1995, the Foundation for Research Development (FRD) and the HSRC jointly undertook surveys on scientific literacy and attitudes toward science as part of a larger project toward the publication of the first *South African Science and Technology Indicators Report* in 1996. The publication presented various indicators on the overall performance of the South African science system, similar to the biennial USA-NSF *Science and Engineering Indicators.* The chapter on public understanding of science included the results from three (3) surveys run concurrently within the same sample population. Using the HSRC Omnibus survey, data was collected between 4 September and 6 October 1995 and fieldwork was conducted by a research company using a national field force and trained interviewers. The questionnaire was jointly developed by the FRD and the HSRC based on similar questions in international surveys. Where

[23] Terminology related to Black racial groups are used as in the original pre-1994 study, often used interchangeably with the term 'African', however remains relevant today in terms of illustrating the impacts of apartheid and racially segregated education systems on non-white South Africans.
[24] It is important to note that at this time South Africa had 18 different education departments, based on geo-political areas and racial classifications. Each department offered a different quality of education to its respective population group, resulting in variations across a national comparison- See Laugksch, 1996 Chapter 1.

required, questionnaires were translated into the various home languages of respondents, based on location within the sampling design (FRD, 1996). The sample was designed to reflect the population of South Africa in terms of race, gender and age in accordance with the 1991[25] population Census figures. Based on the sample characteristics and upon completion of fieldwork and data validation operations, a total sample of 2 163 respondents were included in the final study (FRD, 1996). The survey used three question sets, assessing differing dimensions of scientific literacy among the target population. The first question set included 12 items related to natural and environmental factual knowledge. The second question set included five (5) statements assessing respondents' attitudes toward science and the third question set covered aspects related to human sciences literacy using 13 *agree / disagree / don't know* statements.

Results of the survey on *natural and environmental science literacy* indicate that South Africans generally fared poorly compared to similar items on international studies. On average, South Africans in 1995 answered 5.11 questions correctly out of the 12 questions in this set. On a ranking of 20 international studies employing a similar question set, South Africa is ranked 18th out of the 20 countries, performing better than Russia (4.77) and Poland (4.33). The top scoring countries in this ranking were Canada (7.58), New Zealand (7.52) and the UK (7.49) while the USA ranked 7th with a score of 5.57 (FRD, 1996). Three of the questions in this set were related to radioactivity, and on average, South Africa provided the least number of correct responses (38%) to knowledge questions out of the 20 international countries compared in the report. A further two questions were related to issues of greenhouse gases and the environment; here South Africans performed better than in the previous three (3) questions, attaining a score of 52% and placing in 16th position. A notable result on these questions, in contrast to results from Pouris (1991 and 1993) was that *African*[26] respondents scored the highest number of correct answers (32%), followed by white (28%), coloured (22%) and Indian (12%) respondents. As with Pouris (1991 and 1993), questions relating to human evolution were included in this question set and results did not differ from those earlier results, with many South Africans showing limited knowledge about theories of evolution. However, the FRD study did represent a better racial profile of South Africans responses to this question compared to Pouris, who only surveyed black and white respondents. Corresponding to the results of the Pouris study in 1993, more Black (46%) than White (31%) respondents provided correct answers to questions on evolution, but in the FRD study, 36% of Coloured and 65% of Indian respondents provided correct answers.

[25] As mentioned earlier, these demographic profiles lacked sufficient population coverage and relied on a higher degree of estimation, thereby presenting little research relevance to studies in contemporary South Africa, 20 years later.
[26] See footnote 9

The survey on *attitudes toward science and technology* tested the same sample of South Africans using five (5) attitudinal statements requiring dichotomous, mutually exclusive *agree/disagree* responses. These results were then compared to those of 15 international countries where similar questions were asked. In this survey comparison, South Africa ranked 14th, with an average score of 54% (FRD, 1996). The statements used were classified as either *positive* or *negative* toward science. On statements where agreement indicates a positive attitude toward science, South Africa scored particularly low (42%), second only to Japan; however the Japanese score was based on only one of the two questions. South Africans' responses to statements where agreement indicates a negative attitude toward science show a far more negatively skewed attitude toward science, scoring 49.5% and ranking 9th compared to the 15 other comparable countries. On specific items South Africans generally indicated a low appreciation of science and technology compared to other nations. Among South Africans, males (68%) generally indicated a marginally higher appreciation of science compared to females (64%), while Indians showed more positive attitudes toward science (94%) compared to Whites (93%), Coloureds (61%) and Africans (59%).

Human science literacy was assessed using thirteen (13) *agree/disagree /don't know* statements. The questions were subdivided into categories ranging from behavioural and social sciences, to economics, languages, political science and the arts. The average score achieved in this test was 4.51 out of 13 (34.7%). While overall scores were generally low, respondents did fare better at certain human science areas than in others. Males generally scored higher than females in this survey; however it was noted that a relationship between age, highest education level and access to media sources increased scores in these questions. The authors of the 1996 study had noted with concern the generally low levels of scientific literacy as measured by the three tests in this study. They also lamented the generally poor comparison with many of the countries featured in the report, indicating future impacts on trade and competitiveness if measures related to education and training within the population and workforce were not implemented toward changing these indicators (FRD, 1996).

In 1996, as part of his doctoral work, Laugksch conducted a survey among first-time, first-year students at universities in the Western Cape, South Africa. The aims of his research were threefold: 1) to ascertain the levels of scientific literacy of the selected first-year students, 2) to understand the influence of demographic characteristics on measured scientific literacy and 3) to determine the most important variables as predictors of students' levels of scientific literacy (Laugksch, 1999). With a background in education, Laugksch was most interested in assessing "the products" of the South African education system, and thereby scientific literacy as the output. The questionnaire was developed by Laugksch through a detailed process of defining the input material from which a pool of 472 questionnaire items was developed. These test items were then validated through a rigorous process of item validation involving 41 Fellows of the Royal Society of South Africa. Following the validation process, the test items were put through four (4) concurrent pilot tests administered to 966 students and, in the end, the final *Test for Basic Scientific Literacy* (TBSL) was constructed, which included 110 test items (Laugksch, 1996).

The fieldwork was conducted at the five (5) major tertiary institutions in the Western Cape (in 1995), namely: the University of the Western Cape, University of Cape Town, University of Stellenbosch, Cape Technikon and Peninsula Technikon[27]. The test was administered to 6 801 students. However, after sample cleaning and validation, the final result was based on a sample of 4 223 first-time first-year students. The sample was made up of 14% African, 26% Coloured, 2% Indian and 58% White students, across the five (5) institutions, with subject specialisations ranging from human sciences to engineering and commerce. Where possible, Laugksch tried to control sampling to be an accurate reflection of students in the Western Cape, however he does note an under-representation of African and an over-representation of White students, as is to be expected with respect to access to tertiary education in South Africa in 1995 (Laugksch, 1999).

The questionnaire was designed to have two (2) parts. Part A collected demographic, background and personal information of each student to be used later in the analysis with respect to aims (b) and (c) mentioned above. Part B of the questionnaire was the actual TBSL, which consisted of 110 test items assessing scientific literacy of the cohort of students. Laugksch adopted Miller's (1989) three consecutive dimensions of scientific literacy in designing the TBSL, wherein part B of the questionnaire was divided into three (3) subtests. Subtest 1 was the *Nature of Science Subtest* comprising 22 test items relating to understanding of scientific concepts. Subtest 2 was the *Science Content Knowledge Subtest* that included a further 72 items assessing factual knowledge in scientific areas, while the *Science and Technology in Society Subtest* included 16 items, evaluating respondents' understanding of the impact of science on society and daily life. Respondents asked to take the TBSL during regular class times and were given 45 minutes to complete the test.

Laugksch reported that the overall scientific literacy rate as measured by his Test for Basic Scientific Literacy was 36% in 1995 (Laugksch, 1996). Laugksch used the Part A information in the questionnaire to assess students' performance on his scientific literacy measure with respect to their school-leaving results. It was found that students with the highest matric pass results (A or B

[27] Subsequent changes to the South African Higher Education environment has resulted in the merger of the two technikons in Cape Town.

aggregate) similarly displayed the highest levels of scientific literacy in the TBSL (68% and 51% respectively). Also noted was the finding that only 10% of the learners who attained the lowest matric aggregate result (E, F and G) were classified as scientifically literate - again demonstrating the relationship between education and scientific literacy (Laugksch, 2000). Comparing the results of University students to those of Technikon[28] students, Laugksch reported that 26% of Technikon and 42% of University students were classified as scientifically literate, with the results for the University students found to be statistically significant. With respect to population group and subject specialisation, the study reported a statistically significant difference between scientific literacy scores for members of different population groups. Approximately 50% of White and Indian students were classified as scientifically literate, while 25% of Coloured students and 10% of African students were classified as scientifically literate. Laugksch however cautions that Indians made up only 2% of the sample and therefore this higher scientific literacy result must be interpreted with caution (Laugksch 1999, 2000). With regard to subject specialisation, Laugksch reported no significant difference among the sample. As with similar South African and international studies, gender difference did emerge, with males generally achieving higher scientific literacy scores than their female counterparts. Analysis with respect to gender and population group reported a statistically significant result only between African and White respondents in relation to gender, but none for Coloured and Indian respondents.

An important consideration in relation to scientific literacy is the level of exposure to science material, and specifically the number of science subjects taken at high school level. Laugksch reported that the number of science subjects taken in matric[29] did influence scientific literacy scores, with those taking science subjects in school achieving higher scientific literacy scores than those that took none. These results were stratified according to population group and the number of science subjects taken, with White students showing a statistically significant relationship between the number of high school science subjects and scientific literacy, however for Indian, African and Coloured students, this influence was less significant.

The work of Laugksch represents an important contribution in understanding and developing new tools to measure scientific literacy in South Africa. The rigorous steps taken in identifying and developing a new pool of scientific literacy test items and the expert reviews by Fellows of the Royal Society aided in the reliability and validity of the TBSL. Laugksch however points out that the sample for his initial work (1996) was not large enough and had some issues with respect to representivity, particularly for African and Indian populations. The work attempts to assess the output of the South

[28] Now classified as Universities of Technology
[29] At this time science subjects were limited to Physical Science, Chemistry, Biology, Geography and Computer Science

African school system by targeting students at the secondary-tertiary education juncture but also neglects that the vast majority of South African learners that do not continue onto tertiary education. However as a baseline measure, this does serve as a useful tool for continued research in this area.

3.2.4.2 Surveys conducted from 2000 to 2010

Public understanding of science research evolved in South Africa as it did in foreign settings - to include not only scientific literacy measures, but later also included measures of *public understanding*, *attitudes* and *sources of scientific information* measures. In 2001 Pouris conducted a survey on *Public Attitudes and Sources of Scientific Information among South Africans*, among a sample of 1000 households across the major metropolitan areas. The survey methodology replicated the design and collection methods previously discussed of his 1991 and 1993 work. The questionnaire was developed to include test items from the Eurobarometer and USA-NSF surveys as well as record information about access to scientific information and media choices. The survey used face-to-face interviews that lasted approximately 20 minutes.

Pouris assessed levels of interest in eight (8) scientific areas[30] by asking respondents to indicate interest on a 3-point scale – from *very interested*, *moderately interested* and *not at all interested*. Responses were scored out of 100, with a *very interested* response attaining a score of 100, a *moderately interested* response attaining a score of 50 and *not at all interested* attaining a score of 0. The highest rated issues of interest among the sample of 1 000 was *Medical Discoveries* (73%), *Environmental Issues* (69%), *New Technologies* (63%) and *Economic Policy* (62%). Similarly, the level of *Informedness* was measured using the same eight (8) focus areas, and respondents were asked to rate their perceived level of informedness along a similar 3-point scale to the *interest* scale discussed above. The highest rated areas with regards to *informedness* were similar to those recorded for *Interest* and included *Environmental Issues* (52%), *Medical Discoveries* (49%), *Economic Policy* (46%) and *New Technologies* (42%).

Measures related to assessing the attitudes of participants included the *Index of Promise and Reservation* that uses seven (7) statements (4 positive and 3 negative) about science. Respondents' level of agreement or disagreement with these statements here indicates a general positive or general negative attitude in relation to science. Respondents generally indicated strong agreement

[30] Areas include *new scientific discoveries, new technology, space exploration, nuclear energy, medical discoveries, and environmental issues, foreign policy, economic policy.*

to statements of scientific promise, with top-2 box[31] scores greater than 70%. However, with the reservation statements, 58% of respondents indicated a top 2 box response on the statement *we depend too much on science and not enough on faith* and 69% indicated strong agreement with the statement *science makes our way of life change too fast* (Pouris, 2001). The reservation statement *it is not important for me to know about science in my daily life* received the highest proportion of bottom-2 box responses (59%), however - with the high levels of interest and informedness as well as positive attitudes as measured by the promise index, this is to be expected within this sample group. Lastly, sources of scientific information were assessed, with the most important source of scientific information being magazines (77%), television (66%), newspapers (57%), public libraries (41%) / other public access facilities made up the remainder of the *access to information* scores. The use of the Internet was not highly rated and received 19% of scores, which was similar to Zoo and Museum visits.

In 1999 – 2001 William Blankley and Robyn Arnold conducted a study to assess scientific literacy among a nationally representative sample of 2 207 individuals of both genders and across all race groups. The purpose of the study was to collect information on public civic scientific literacy, with the aim of understanding the current level of literacy in the South African population and to aid in defining the relevant target audience(s) as well as the development of enhanced intervention strategies. The questionnaire adopted many international measures, as in Pouris and the previously mentioned HSRC studies, but some locally developed test items were also included to adapt the questionnaire to local conditions for increased relevance in South Africa (Blankley and Arnold, 2001). The sample was constructed to include adults aged 18 years and older, and was matched to population census figures[32]. Blankley and Arnold investigated scientific literacy but also looked at other demographic factors that may influence scientific literacy scores, as did Laugksch (1996). Blankley and Arnold found that the relationship between mathematics and science subjects taken at school was positively related to scientific literacy scores. In their 2001 paper they report that within the sample, 30% of adults had never studied mathematics at school, 50% had never studied biology and 55% had never studied physical science or chemistry. They also reported that the number of adults reporting having taken (or currently attending) science related subjects decreased as educational level increased – at matric level only 20% passed mathematics, 14% physics and 18% biology, while at tertiary level this decreased to below 5%. It was interesting to note that these results were skewed to more older people, as in 1999 – 2001 post-apartheid era schooling was changing these patters for younger people, while older respondents were still reporting their

[31] Top-2 box is the summation of the scores for *Agree* and *Strongly Agree*. Bottom-2 box is the summation of *Strongly Disagree* and *Disagree*

[32] Appropriate weighting was applied in accordance with the demographics of the South African adult population.

educational history from before 1994. As in previous studies, more males report having taken and passed science subjects than females. Similarly, Blankley and Arnold also found that qualifications and educational background in science not only led to enhanced scientific literacy results, but also better employment and reported income (Blankley and Arnold, 2001). Further segmentation by population group revealed similar results to earlier studies with African and Coloured respondents reporting lowest exposure to scientific education and consequently, lowest scientific literacy scores.

Attitudes toward science and technology questions were also included in this study and used the *index of promise and reservation* in order to appraise public attitudes toward science. South Africans generally reported agreement with more positive (promise – 76%) than negative (reservation – 60%) items. Blankley and Arnold also report on the ratio of these indices (promise score: reservation score) and compare the results to 13 other countries reporting *Promise and Reservation index* scores for the same (or a similar) year. South Africa reported an index score of 1.28, that compared favourably with the 13 other countries and ranked 4th, between Italy and Ireland, scoring higher than Great Britain, France, Germany and the Netherlands. This indicated that in 1991-2001 South Africans were generally optimistic about science; however Blankley and Arnold do assert that this may in fact be due to the lower levels of factual knowledge and understanding about science that allows for this greater optimism (Blankley and Arnold, 2001). This is emphasised when the results of the index of promise and reservation is analysed by respondents' highest educational level, wherein we see that for the lowest educated groups the correlation is +0.28; while for the highest educated group this correlation is +0.09. This contrasted to the USA where the correlation for the entire population is -0.66, indicating greater reservation about science which appears to be further negatively impacted by higher educational attainment. Questions relating to public understanding of scientific terms and concepts were also included. A general global trend emerged here wherein simple concepts (*The oxygen we breathe comes from plants*) were generally answered correctly (80% answered correctly) while more complex concepts (*antibiotics do not kill viruses*) were generally not answered correctly (14% answered correctly). Levels of interest in scientific areas were also assessed and revealed the following results (table 3.7):

	African	Coloured	Indian	White	Total sample
Level of interest : New Scientific Discoveries					
Very interested	47.7	42	36.9	37.5	45.5
Moderately interested	32.1	31.4	45.6	49.8	34.8
Not at all interested	20.2	26.6	17.5	12.7	19.7
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Level of interest : New inventions					
Very interested	46	36.2	39.3	44.8	44.7
Moderately interested	34.3	34.1	43.7	43.7	35.9
Not at all interested	19.7	29.7	17.0	11.5	19.4
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Level of interest : Medical discoveries					
Very interested	54.3	51.3	47.6	57.3	54.3
Moderately interested	27.1	28.7	42.5	32.5	28.4
Not at all interested	18.6	20	9.9	10.2	17.3
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Level of interest : Environmental issues					
Very interested	49.2	38.5	37.4	51.8	48.2
Moderately interested	33.4	36.0	47.7	41.5	35.2
Not at all interested	17.4	25.5	14.9	6.7	16.6
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 3.7: Interest in science, all races. Adapted from Blankley and Arnold, 2001

As in Pouris 2001, interest in Medical Discoveries remained the most widely reported area of scientific interest, followed by environmental issues, new scientific discoveries and new inventions. This is promising, as interest would be key toward ensuring that intervention strategies aimed toward promoting scientific literacy would be successful (Blankley and Arnold, 2001). Analysis of this data by population group revealed that there was a high level of interest among the lowest income groups - historically also the poorest performers on measures of scientific literacy - and thus further highlights the importance of developing strategies to rapidly effect change among these groups. Blankley and Arnold note in their conclusion that any intervention strategy that is developed to target specific audiences in South Africa must take into account the 'limited scientific knowledge and vocabulary' among the general population. This would likely be a dual approach, heavily dependent on government policy shifts, to lay better foundations for younger people at school level while simultaneously ensuring that adults are provided with similar learning opportunities in order to raise their scientific literacy and thereby prospects for a more prosperous future.

The study of the public understanding of science evolved between 2000 and 2010 with two studies highlighting the importance of science communication and its relationship to scientific literacy and public attitudes and understanding. This reflects the similar evolution in Europe much earlier toward a more *science and society* focus within the research paradigm. Goolam in 2001 investigated the levels of scientific and technological literacy of first-year physics students at the University of Pretoria. The study employed both qualitative and quantitative research approaches using a survey questionnaire as well as focus group discussions. The questionnaire was divided into questions assessing scientific literacy as well as a section asking questions on technological literacy. The differentiation between scientific literacy and technological literacy is important as not all citizens will find scientific principles and concepts useful in daily life. However, in a modern urban environment, technology and thereby technological literacy becomes valuable in navigating the many solutions based in recent technological advances (Goolam, 2001). The focus groups explored the understandings of selected survey respondents' understanding of scientific literacy and technological literacy as well as how the public determines competency in each of these literacy areas. Goolam identified four (4) scientific literacy levels in his study: *Scientifically Illiterate*, M*ediocre Scientific Literacy*, *Good Scientific Literacy* and *Excellent Scientific Literacy*. Goolam scores his questionnaire out of 20[33] possible points, and of the total sample of 171 students, 17% were found to have *excellent scientific literacy*, 47.3% to demonstrate *good scientific literacy*, 28.1% displayed *mediocre scientific literacy,* while 13 % of students were found to be *scientifically illiterate*. A similar tabulation was performed for technological literacy, wherein it was revealed that 75.5% of students surveyed demonstrated a *good* to *mediocre* level of technological literacy.

Similarly in 2004, Conradie conducted a study as part of her doctoral work that investigated *the role of key role players in science communication at South African higher education institutions*. The study held as its focus the understanding of the key role of science communicators in disseminating science messages in South Africa. Conradie highlights 4 categories of communicators of science including: scientists, communications specialists at universities, journalists and executive management at universities. In doing so, she identified six aims of this research: 1) to determine the importance of science communication among role players, 2) to determine if a relationship of trust exists between these role players, 3) to understand the role of a communications specialist, 4) to understand the extent of communications training provided to scientists, 5) to assess scientific media coverage in South Africa, and 6) to perform a media analysis on science coverage in major media between March and May 2004. Key findings delineated by the six aims of the study included: 1) science communication is important to all role players in the scientific community; however more needs to be done to communicate science to the general public to increase scientific literacy, 2) greater effort needs to be invested in developing trust relationships between key role players in the South African S&T system, 3) communication specialists are regarded as managers, but lack effective power to perform their jobs to an effective degree, 4) results indicate that adequate training for communicators, journalists and scientists is still lacking, 5) for aims 5 and 6, the study concluded that media coverage related to science news still remains very low compared to other interest areas. Conradie notes that science communication and its role players play a crucial role in building an enhanced public understanding of science toward developing a more scientifically literate population. She contends that a pro-science environment needs to be developed in areas where the public and science interact toward fostering better relationships and a greater sense of understanding and knowledge transfer. However, she continues to stress the importance of up-stream changes that must evolve as both the public and scientific development evolve, wherein key role players in the system are empowered and have the capacity to meaningfully engage and attract

[33] Where less than or equal to 8 = *Scientifically Illiterate,* 9 to 11 = *Scientifically Illiterate,* 15 to 15 = *Scientifically Illiterate* and 16 to 20 points = *Scientifically Illiterate*

the interest of the public toward the stated goals of the public understanding of science and science communication community.

Van Rooyen (2004) conducted a similar study on public understanding of science through media analysis and in her work revealed that science coverage in the media is not at a sufficient level and quality that would make it a priority in society and government policy. Her report, based on an analysis of 15 major South African publications[34] over a period of three (3) months between March and June 2002, revealed that only 2% of editorial space was devoted in some way to science coverage. On a positive note, van Rooyen reports that of the news articles reviewed in this period, 70% adopted a positive reporting stance with respect to scientific issues, while 30% expressed a more 'negative' perspective. The review of media coverage revealed nineteen (19) categories of science reporting, with the most popular being biomedicine (18%) followed closely by astronomy[35] (14%). Van Rooyen also found that in addition to the above, a fair amount of coverage was given to issues related to HIV/Aids research (12%) and high-tech issues (12%), while a higher proportion of coverage dealt with topics of pseudo-science (5%), such as astrology, and only a very small percentage of articles covered mathematics (0,2%) and physics (0,4%) (Van Rooyen, 2004). In a similar media analysis study in 2010, Gastrow, as part of a report for the National Advisory Council on Innovation and the National Biotechnology Advisory Committee, reported results which concur with that of Van Rooyen's earlier study. Gastrow did expand on the work of Van Rooyen methodologically; however, essentially the results had not differed greatly from the earlier work and will not be discussed further.

In addition to evolutions in research approaches, the subject focus area of public understanding of science work also began to pay attention to specific scientific fields. Whilst as a field of science, Biotechnology is in its infancy, climate change and climate research has been ongoing for at least the last 60 years. However with the recent politicisation and media coverage in relation to both areas of science, increased public awareness, public opinion and public interest have resulted in surveys appearing toward studying this branch of discourse. In 2004 the HSRC conducted a *Public Understanding of Biotechnology Survey* on behalf of the Department of Science and Technology (DST). Their survey used items from the USA-NSF and Eurobarometer surveys in assessing attitudes, interests and understanding related to biotechnology among the general public. The sample was selected from within the HSRC Master Sample using 500 enumeration areas and selecting 7 000

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[34] Daily newspapers included: Die Burger, Beeld, Cape Argus, The Star and the Sowetan. Weekly newspapers included: *City Press, Mail & Guardian, Sunday Independent, Sunday Times, Rapport and Business Day*. Non-Science magazines included: *Financial Mail and Finance Week*. Community newspapers included: *Eikestadnuus and Sasolburg Bulletin*

[35] This may have been influenced by the much publicised "First African in space", Mark Shuttleworth's visit to the Mir International Space Station.

adults, 16 years and older. The demographic representation was scaled to be relative to population Census data. Results indicate people are generally supportive of technologies that will ensure food security and quality, but remain conservative in their support with respect to the health and environmental implications of biotechnologically engineered foodstuffs. This reveals a general sense of ambivalence within the sample group, indicating the public is not absolutely certain about the fair and ethical application of biotechnology. A similar pattern is exposed in the 2007 HSRC–SASAS (South African Social Attitudes Surveys) survey of *Public Understandings of Climate Change*. Completed in the SASAS survey, it had similar sample design, makeup and operational specifications. The questionnaire was developed by the HSRC and the final sample used from which the results were obtained comprised 3 164 respondents (Reddy *et al*, 2009). In results similar to that of the *Understanding of Biotechnology Survey*, the climate change survey revealed that the South African public still has not taken up the concerns relating to issues of climate change as the numerous and often conflicting 'evidence-based discussions" generally leave the public more confused than concerned. Results indicate that 27% of respondents had not heard of 'climate change', while at the same time 25% indicate that they are '*fairly dissatisfied*' by the government response to issues of climate change. There was little variation in these results when contrasted along varying demographic variables, indicating that especially for *age* and *education*, the consistency in the result may be attributed to an external learning environment from school or work. Reddy *et al* (2009) attributes this to patterns of media coverage in South Africa in relation to climate change. In the total sample of 3 164, 46% indicated that they had become more aware of issues related to climate change in the recent past as a result of increased media coverage and available information sources, yet indications are that concern related to issues of climate change in South Africa remain low.

3.2.4.3 Surveys conducted from 2010 to present

The period from 2010 to the present has not seen as many studies being published. However, concerted efforts by the HSRC and its research partners have delivered some interesting research products, albeit as a return to survey orientated research. Much, though not all, of the empirical work conducted by the HSRC since 2010 has been conducted using the South African Social Attitudes Surveys (SASAS). The survey is designed to collect information from a large representative sample of South African adults aged 16 years and older. The sample size is usually made up of between 6 000 and 7 000 adults representing all races, genders and age groups from across South Africa, both rural and urban. In 2010 the Education and Skills Development research programme of the HSRC conducted a survey using a module in the SASAS survey designed to assess public attitudes to science in South Africa. This is was the first time[36] that a general public attitude to science survey had been conducted since Blankley and Arnold (2001). The survey yielded a total of 3 183 respondents, with 48% male, 52% female, 77% African, 9% Coloured, 3% Indian and 11% White participants. Both rural and urban respondents were surveyed and where required, questionnaires were translated and interviewers were fluent in local languages of research areas (Reddy *et al*, 2009). In addition to responses on public understanding of science items, the questionnaire collected data on geographic, cultural, economic, social and demographic data points. The survey adapted the *Scientific Literacy*, *Public Understanding of Science* and *Science and Society* research paradigms into the *Publics Relationship with Science* research paradigm (Reddy *et al*, 2009; 2010). The questionnaire included questions that related to the specific social and cultural dimensions of the South African social context, but questionnaire elements continued to include an *index of promise and reservation*, scales to measure *attitudes toward science* as well as *levels of interest* and *information sources*. As selected items were adapted from the USA- NSF and the Eurobarometer surveys, this study was able to present some international comparisons for more recent South African public understanding of science data as well as trend analysis with previous comparable surveys conducted domestically.

Results from the Index of *promise and reservation* illustrating the general attitudes of the public with respect to selected issues in scientific areas indicate a generally more negative public attitude with regard to science in South Africa. Specifically on the statement, *we depend too much on science and not enough on faith*, results from the 2010 survey show a 17-point increase in general public agreement with this statement; similarly, with the 5-point increase in agreement with, *science makes our lives change too fast*. Promise and reservation index data analysis for age, gender and population group was not presented in their finding. Comparisons were however presented with international surveys with comparative datasets. South Africa obtained a *Promise/Reservation Index* score of 1.20, followed by India (0.80), while the USA (1.70) and European (1.40) scores all ranked higher. Reddy *et al* (2010) have further presented a positive correlation between GDP and *Promise / Reservation Index* score changes across this same period. They reported that South Africa had a similar response pattern to that of Europeans on certain test items, while on others reflected a pattern closer to that of respondents from India (Reddy *et al*, 2010). Attitudes to science were disaggregated by educational level, age and gender in an effort to best understand the varying strata of the South African public. There were no striking variations for attitudes to science with respect to gender; however, age was shown to demonstrate a significant effect on attitudes toward science. Younger participants (16-19 years old) showed a greater sense of scientific promise and

[36] Rather than surveys related to specific focus areas or exploring other methodological approaches – media analysis.

consequently more positive attitudes toward science compared to older age groups. Similarly, as educational level increased, so too did *positive attitudes to science* and a greater sense of scientific promise, compared to respondents reporting lower academic attainment levels. These results are echoed in the data for the comparable surveys from India and the USA. The authors note, in general, that avenues for further research within selected 'publics' could be identified through more detailed analysis of these survey results. Further areas also carry implications for science communication and public science policy in general.

Public understanding of Nuclear Technology/Energy was investigated by the HSRC in 2011, again using the SASAS survey. Results in the survey indicate that 23% of respondents report being in favour of nuclear energy, however SASAS further reports that a similar number was ambivalent in their attitude toward nuclear energy, while 42% responded with the "*don't know"* option. Comparisons to similar European surveys indicate that this level of ambivalence is four (4) times higher in South Africa, with the British survey revealing 11% responding with the '*don't know'* option (Struwig and Roberts, 2011). Respondents in the survey were asked to identify *benefits* and *disadvantages* of nuclear power as a source of electricity in South Africa and many expressed support and positive attitudes toward nuclear power. The study reports that 23% of respondents would consider nuclear a *reliable energy source*, 16% felt that it could assist *in alleviating climate change* while 14% indicated that nuclear energy represents a more cost-effective energy source. With respect to the disadvantages of nuclear power, respondents were most concerned about the risk of nuclear accidents (34%) and the ethical disposal of waste by-products (20%), and 19% expressed a concern related to the risk of radiation contamination. Responses in the 'don't know' category were equal for both the *advantage* and *disadvantage* statements (50%). Despite the safety concerns, 40% of respondents agree that the South African nuclear energy programmes should continue to operate, while a further 44% were not sure (reported the '*don't know*' response option). A further 38% of respondents agreed that South Africa should build new nuclear power generation points, adding to the current capacity. However, again, 42% responded with the '*Don't know*' response option (Struwig and Roberts, 2011). The authors note the generally lower levels of public understanding of nuclear technology, attitudes toward nuclear safety and risk perception as key areas to be addressed by appropriately nuanced communications channels. Government and the nuclear industry as well as academic and other related role players have all been identified as key to increasing the general public understanding of nuclear power as well as highlighting the importance of appropriate public support for future expansion of the domestic nuclear power programme.

The International Trends in Mathematics and Science Survey (TIMSS) has been conducted since 1995. Though TIMSS is designed to assess the performance of grade 4 and 8 learners, it did in certain year's survey other grades. The survey is designed to reflect the school curriculum and asks learners to use information presented in the questionnaire to solve problems posed, as a means of assessing the degree to which learners have developed competencies and assimilated concepts in maths and science as well as the degree to which this can be applied to presented scenarios. South Africa had participated in TIMSS since 1995 and again in 1999, 2002 as well as the most recent survey in 2011 (HSRC, 2011). As key areas of higher and tertiary education as well as employment competency, mathematics and science performance is of paramount importance to assessing the literacy rates within these areas at an early stage. Further to this, it provides valuable international comparison for youth populations as a useful future indicator as well identifier of areas for additional focus and planning.

In comparing TIMSS performance between 1995 and 2002, results indicate that the average national score remained unchanged; however, within provinces, increases were noted (HSRC, 2011). Scores increased by 63 points at private schools and by 60 points at public schools, indicating a 1.5 grade level improvement in the 2011 round of the survey. Similarly, the 1995 to 2002 results indicate a wider range of scores between the 5th and 95th percentile. However in the 2011 iteration of the survey, this decreased substantially, indicating a possible improvement in providing more equitable education, particularly at schools in lower income communities (HSRC, 2011). Scores for mathematics increased in all provinces except for the Western Cape, but this was not found to be statistically significant. Similarly, for science scores, all provinces recorded increases, with Gauteng recording the highest increase in both maths and science scores. While here were differences in performance between the provinces, comparison to provincial results from the 2002 survey indicate an 80 point decrease in the difference of scores between the highest performing province (Western Cape - 421) and the lowest performing province (Eastern Cape - 282). Nationally, and for both mathematics and science scores, girls outperformed boys, though this difference was not found to be statistically significant. There were, however, age differences recorded within these scores, where girls younger than the grade average outperformed boys. At age-grade appropriate levels boys however outperformed girls, and where learners were older than the grade average, no statistically significant difference was observed (HSRC, 2011). With regard to attitudes toward science and future careers, learners generally value science and mathematics education; however, they reported a lower confidence in the quality of education in these subjects. This result indicated a decrease in learner confidence between 2002 and 2002, from 10% reporting low confidence in 2002 to 24% reporting this in 2011. The majority of learners (54%) reported a desire to continue on to tertiary education, only 2% lower than similar scores for their international counterparts in the 2011 survey. While TIMSS presents a useful snapshot of future adults in a country, and for South Africa illustrates a promising positive trend for science and mathematics educational outcomes, its methods fundamentally present limited applicability to public understanding of science research due to its targeting younger learners as well as its specific focus on school curriculum competency areas.

The above review of selected studies represents the major empirical works in South Africa since the early 1990s. Table 3.8 below presents a summary of work reviewed as well additional works not discussed above[37]. From a detailed reading of the number of empirical research reports on the public understanding of science and scientific literacy in South Africa, it is clear that as a country in transition, a number of improvements have been recorded, though many authors (see above) have stressed the importance of an increased and more focused effort toward enhancing educational inputs and outputs as a means to generally impact measured public scientific literacy and general understandings of science. The earlier noted evolution in methodology and paradigmatic approaches - from measures of scientific literacy to public attitudes and understanding of science as well as the social approach under the science and society paradigm that included research with media analysis and science communication actors - reveals a field of study that is increasingly valuable to South Africa's developmental aspirations and stated economic, political and social goals. The numerous changes that the South African social structure has seen since 1994 appear to be influenced by social and cultural assimilation to a more democratic and globalised notion of human–science– technology interaction. While South Africa is still considered a developing economy, it simultaneously displays a number of characteristics of more developed nations, thereby making a detailed understanding of the public's interactions, attitudes, knowledge, risk perceptions and general competency with respect to areas of science even more important.

uthor	Title	Year	Survey Description
Pouris	Public understanding and appreciation of science among the public in South Africa	1991	Face-to-face interviews, Major Metros, random suburb sampling - 1 300 "White" respondents
Pouris	Public understanding and Appreciation of Science among South African Teenagers	1993	Face-o-face interviews, Major Metros - 800 "African" and "White" respondents

[37] Where studies were sufficiently similar in design, results and relevance, these were not included in the review in table 3.8

HSRC	Omnibus Survey	1995	Face-to-face interviews
IEA	Trends in International Mathematics and Science Study (TIMSS)	1995	Paper and pencil test administered to grade 8 learners in schools
FRD-HSRC	SA Science and Technology Indicators - Public Understanding of Science chapter	1995	3 surveys measuring scientific knowledge, Attitudes to Science and a survey on Human Science Literacy - 2 163 respondents
Laugksch	Test for Scientific Literacy and its application in assessing scientific literacy of matriculants entering universities and technikons	1996	Survey of 1st time entering university students at Western Cape Universities - 4 227 respondents
HSRC	EPOP	1999	Household survey using face to face interviews
IEA	Trends in International Mathematics and Science Study (TIMSS)	1999	Paper and pencil test administered to grade 8 learners in schools
Pouris	Interests, Public Attitudes and Sources of Scientific information in South Africa	2001	Face-to-face interviews, Major Metros, Representative Cluster sampling - 1 000 households
Blankley and Arnold (FRD)	Public Understand of Science in South Africa – aiming for better intervention strategies	2001	Face-to-face interviews, Major Metros - 2 207 randomly selected (18+ years old) respondents
Goolam	The scientific and technological literacy of first year physics students: the effects of a traditional school curriculum	2001	Mixed methodology survey - 171 students in 1st year of physics programme at University of Pretoria
HSRC	SASAS: Biotechnology survey	2004	Household survey using face to face interviews - 7 000 respondents aged 16+ years

IEA	Trends in International Mathematics and Science Study (TIMSS)	2003	Paper and pencil test administered to grade 8 and grade 9 learners in schools - 8 952 respondents
Pouris	Assessing Public Support for biotechnology in South Africa	2004	Face to face interviews in consumer survey - 1 000 households
Conradie	The role of key role players in science communication at South African higher education institutions: an exploratory study	2004	2-phase study at South African Universities: Phase 1: Survey interviews with 102 science communicators. Phase 2: Content analysis in 16 South African publications
World Values Survey	World Values Survey	1990-2005	Household survey using face to face interviews - 2 988 respondents
HSRC	SASAS: Climate change	2007	Household survey using face to face interviews - 3 164 respondents
Reddy *et al*	Public Understanding of Science in South Africa	2010	Face –to-face interviews, rural and urban, 3 183 respondents aged 16+ years
HSRC	The Public Understanding of Biotechnology in the Media	2010	Content analysis of 4 major news publications in South Africa - 50 articles
HSRC	Trends in International Mathematics and Science Study (TIMSS)	2011	Paper and pencil test administered to grade 8 and grade 9 learners in 285 schools - 11 969 respondents
HSRC	SASAS module: Public Attitudes Toward Nuclear Technology and Energy in South Africa	2011	Household survey using face-to-face interviews - 3 057 respondents aged 16+ years

Table 3.8: Empirical studies of Public Understanding of Science research in South Africa. Adapted from Reddy *et al*, 2009

Conclusion

This chapter reviewed the historical overview of public understanding of science and scientific literacy research. It presented a comprehensive literature review of the major theoretical and methodological approaches to the study of scientific literacy and the public understanding of science. The historical development of this field in the United States of America as well as the European and wider context has led to numerous methodological and empirical advances in understanding of the public-science rendezvous points. As a result of the dynamic and changing environment within which this multidisciplinary area of research is located, the evolving definitions and debates that ensued in the late 1980s internationally has left the domain far richer, though no closer to a consensus within which to advance in a single direction. This is by no means a negative outcome; on the contrary, it has opened and expanded the agenda for research as well as the development of the next phase of evolution toward the development of reliable indicators of the public understanding of science.

The section reviewing empirical studies presented research from 10 countries delineated by broad development-status identification. It had become clear that within the developed world, a number of large international surveys (PISA, TIMSS) have been conducted and results presented reveal emerging trends that appear consistent across geographical regions. Similarly within the developing world context, cultural and social conditions may vary internally and between countries, thereby fundamentally challenging accepted approaches to the study of scientific literacy and the public understand of science. Though initial research within the developing world adopted western survey instruments and approaches, empirical studies have found these methods inadequate, and continual revisions as well as development of locally relevant test items are ongoing, while consistently requiring a comparison point to other international findings to maintain relevance.

A detailed review of studies conducted in South Africa was presented to illustrate the influence of social and cultural context. South Africa is uniquely positioned to do this due to its demographically, economically, socially and culturally diverse population; leading Reddy *et al* to refer to these as *the South African public**S*** (2009). While a demographically representative survey of South Africa's public understanding of science had been conducted in 2010, test items and the questionnaire design of that survey have identified broader areas of interest for investigation toward the development of a more focused and appropriate instrument for the measurement of these important metrics. Lessons from the review of Chinese studies have stressed the importance of definition and the reliance on an appropriate design for the particular social context. This is in agreement with Shamos, Shen and

Popli, and furthermore seems most applicable to the future of South African empirical research within the public understanding of science domain.

The next chapter adopts this challenge by first reviewing the history and development of scientific literacy and public understanding of science indicators as well as the debates they engendered then and still do today. Following this, the empirical approaches to this research will be presented within the context of indicator development toward the identification of appropriate indicators for the South African context. The outcomes of the discussions in the following chapter will result in the development of an appropriate research instrument for the empirical part of this study that will inform a set of indicators of the South African public understanding of science.

Chapter Four

Research Instrument Development

Now it is time to be ambitious again, let researchers come together with new efforts…

(Bauer et al. 2007)

The development of the research instrument within this study required detailed reading of the literature and related resources toward gaining an in-depth understanding of the history and development of measurement in the area of scientific literacy and the public understanding of science. This chapter introduces into these discussions the history of science and technology indicators and specifically, statistics of scientific literacy and the measurement of public understanding. Having to take into account the uniqueness of the South African context while simultaneously remaining aware of the shared global context within a knowledge economy means the production of science indicators in the developing world can be likened to walking a tightrope. It requires a fine balance between localisation and international comparability to ensure the effectiveness of indicators and, ultimately, the accuracy of the research findings.

This chapter introduces the elements considered salient within the measurement of the South African public understanding of science. These elements are then operationalised within the research instrument toward the measurement outcomes. Within the research instrument discussion, the rationale, design, development, quality assurance procedures and implementation of the survey are discussed. The chapter concludes with a discussion of the data outputs and indicators produced within this study.

4.1 SCIENTOMETRICS and INDICATORS for the PUBLIC UNDERSTANDING of SCIENCE

4.1.1 A BRIEF HISTORY OF SCIENCE and TECHNOLOGY INDICATORS[38]

The history of formal institutional science and technology measurement can be traced back to 1962, with the OECD producing the early *Frascati* Manual for the measurement of *research and development* activities (Goudin, 2001). However, historians of the *sociology of science* note the earlier quantification of smaller scientific communities. These activities included recording numbers of individuals actively involved in professional or semi-professional scientific activities as well as related audits of instruments and capabilities in the interest of strengthening and preserving the scientific enterprise. The statistics output during this initial period (mid-19th century) spoke to the

[38]While much has been written on the history of STI indicators, this section presents a highly abridged account – for greater detail see Goudin 2000, 2001 and 2010

early culture of science which in many domains still continue relating the socio-political context and its imperative to produce increasing numbers of scientists as an early indicator of social-scientific advancement and development (Goudin, 2010).

The measurement of key inputs into the science system, including financial, human resources, infrastructure investment and societal support have advanced along three periods of development. Goudin (2010) highlights these three periods in the historical development of science statistics chronologically in Table 4.1 below.

Stages	Source	Main statistics
Emergence (1869-circa 1930)	Scientists	Number of scientists
Institutionalization (1920-circa 1970)	Governments and national monetary expenditures statistical offices	Monetary expenditures
Internationalisation (1960 and after)	International organizations (UNESCO, OECD, European Commission)	Technological innovation (indicators and international comparisons)

Table 4.1: Historical Development of Statistics on Science (from Goudin, 2010, page 8)

These periods in the development of science measurement evolved within two communities of practice. The first of these is the *academic tradition*, including economists and sociologists of science who were primarily interested in the production of models to explain linkages across the scientific system. The second tradition emerges within Institutionalised organisations such as the Organisation for Economic Co-operation and Development (OECD) and the National Science Foundation (NSF), and collates, among other data, indicators on national science systems (Goudin, 2010). The type of statistics produced within these two traditions could in many ways be related to the influence of *interest groups* discussed in Chapter Two, wherein the outputs of research reflect the intended use and application of data consumers within their particular worldview. Arie Rip (1997) developed a graphical representation of the varying views different role players may have of the scientific enterprise, based on the traditions and worldview from which they emerge. Figure 4.1 displays this varying perspective that may in some respects offer a differing interpretation of the same data, as a result of these interpretative disparities.

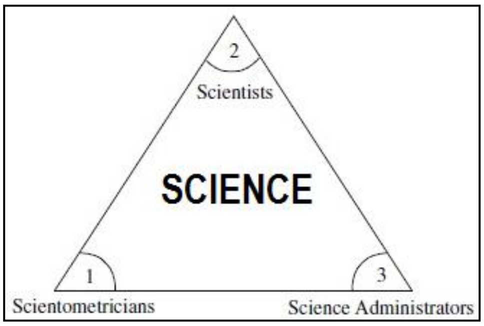


Figure 4.1: Graphic representation of Rip's Triangle (image from Feller & Gamota, 2007)

Similarly, Fred Gault (2011) notes that, '*… indicators, of any kind, are developed as a result of a perceived need of a community that wants to use them; both the development process and the eventual use of the indicators have social impacts*.' Gault clearly identifies that beyond the scientometric development of indicators, the social and cultural environment within which indicators are developed and applied are of equal importance and value. He further notes the iterative nature of indicator development wherein input from data users and producers further refines the development of indicators.

The *Linear Model of Innovation* generically represents the stages of scientific research and development *inputs*, *activities*, *outputs* and *impacts* along a linear process. Since the 1960s the traditions and operationalisation of science measurement has seen increasing contributions in the form of new methods as well as additional measurement manuals relating to *Technological Balance of Payments* (1990), measurement of innovation activities - *Oslo Manual* (1992) as well as manuals describing methods of measuring patent indicators (1994), human resources – *Canberra Manual* (1995) and productivity (2001). While the advancement in science, technology and innovation (STI) measurement is generally appreciated and the large volumes of global measurement databases now span almost 60 years of data, numerous elements within the scientific processes are poorly (if at all) measured. Freeman and Soete (2007) note the focus on *input* measurement (financial, human resources etc.), due to the convenient nature of *inputs* toward measurement; compared to more abstract constructions of *outputs* and *impacts*. Godin (1996, in Godin, 2000) notes that the further one moves on the linear model, away from inputs and toward impacts, the fewer scientific measures and indicators are available. More recent models of *science & society* have remedied the linear models' propensity to unduly attribute scientific research as the only area of innovative activities, opening up the discussion to the many social and culturally inter-looped structures at play throughout the innovation life cycle (Edgerton, 2004).

The aforementioned 'measurement accessibility' of input flows, compared to the more abstract constructs within *output* and *impact* measures, emerged as a result of the drive within governments and institutions to promote administrative efficiency and effectiveness of investments with respect to defined research objectives (Godin, 2000). This is of particular importance for measures of *output* and even more so for *impact* measures, of which very few (if any) widely accepted metrics exist. Within the area of public understanding of science (PUS) measurement, this represents a particularly important juncture, as PUS data reflects both an impact of the science system and as a driver of human resource development. Similarly, PUS data acts as a type of pre-input into the science system, providing the much-needed human-resource capital and a suitably scientifically-skilled public more receptive to scientific innovations. The importance of human capital within a scientific context provides the gravity around which the varying stakeholders within the system must align toward building greater capabilities and efficiencies and increasing outputs and impacts of a national system of innovation. Similarly, additional social factors such as education, infrastructure and government support remain important to ensure a competent downstream supply of human resources, both within the science system, and as supporting actors in the form of a scientifically-attentive public.

South Africa has yet to develop a routine assessment of the public-science milieu as the country moves ahead in its various expansion initiatives driven by an ICT[39]-based environment, the understanding of science and technology within society will become increasingly important. The following sections explore the potential for the development of public understanding of science research, indicators and the relevant social and contextual elements paramount to the success of such initiatives.

4.1.2 STATISTICS of SCIENTIFIC LITERACY and PUBLIC UNDERSTANDING of SCIENCE

The earliest surveys of *scientific literacy* and *public understanding of science* research emerged around the mid-1950's. Since then a formidable time series of data has been (disparately) amassed, particularly in the United States of America and Europe, with limited Asian and developing countries similarly producing multiple contemporary datasets[40] (Bauer and Falade, 2014). However, related to this is the long-standing debate within the research community with respect to a *universally* accepted definition of *public understanding of science* and *scientific literacy*. Chapter Two discusses in detail the many historical debates related to the *evolution of meaning* chronologically across the preceding 70-years of research contributions within this domain. These debates relate specifically to what exactly *scientific literacy* (and later *public understanding of science*) should entail, to whom it is applicable, which *publics* should be measured, how it benefits society and the concept of *deficit attribution* (see: Bauer, Petkova, & Boyadjieva, 2000; Bauer, Allum and Miller, 2007).

However, what has transpired across this period is a general agreement relating to the value of Miller's (1983) *3-consecutive dimensions of scientific literacy*, which has formed the foundations of the early NSF surveys, and continues to inform these flagship products on a regular basis. Through this evolution, the concepts under the umbrella of the *public understanding of science* paradigm added the dimension of *attitudinal measurement* to the area of *scientific literacy* measurement. Similarly as the *Science and Society* paradigm emerged in the early 1990s, despite the rejection of

[39] Information and communications technologies
[40] Previously discussed in Chapter 3

public deficit attribution and the questioning of surveying methods, measurement instruments under this movement returned (albeit from a different vantage) to public surveys, in the absence of more advanced measurement techniques. Despite these many debates and the continuing evolution of meaning and definition, Bauer (2014) maintains that '…*none of the new discourses made the previous ones obsolete, as research continues to enhance and expand the agenda*'. While the definitions, survey methods and statistics have not attracted a complete sense of harmonisation across the field, broad agreement exists relating to the acceptability of current measures, in the absence of a more refined battery of measurement techniques and definitions (Barre, 2010).

With the release of the first NSF *Science Indicators* report to include a chapter on *indicators of scientific literacy* in the early 1990s, similar products began to appear via the European Commission and related statistical and governmental organisations (Godin, 2010). While in many respects, early NSF attempts sought to measure *scientific literacy,* the initial *EuroBarometer* series included a dimension related to *public attitudes* and *interest in science*, expanding on the NSF product offerings. Despite the fact that there are related methodological and theoretical variations between the early NSF and *Eurobarometer* approaches to the study of the public understanding of science and scientific literacy, a point of congruence emerged toward the end of the 20th century, wherein products produced in wider geographic settings adopted similar 'standardised' approaches to measurement within this field. As a result, studies discussed in chapter 3 from the United Kingdom (Wellcome Trust, OST), Japan (NISTEP), China (CAST), Australia (Australian Academy of Science), Malaysia (MOSTI) and developing nations such as India (NISTaDS) and South Africa (HSRC, Pouris, Blankley & Arnold) have all produced similar datasets. While many of these studies have introduced incremental variations and refinements to the measurement of the public understanding of science, the drive toward international comparability of data and (an ill-defined) drive toward standardisation of definition, method and reporting has yielded a number of internationally comparable datasets. Discussions within the developing world particularly have highlighted the need for greater cultural reflexivity within the measurement of the public understanding of science, which has provided much of the impetus within the current global research agenda (see chapter 3). The discussed methodological debates, relating specifically to item selection; the equating of *knowledge of scientific facts* with understanding or 'literacy'; the relationship between knowledge, attitudes and understanding as well as the long-standing matters relating to the applicability of the deficit model and the related questions around its application in various settings have attracted enough consensus toward providing continued advances within the field.

As a result of the above, few indicators of scientific literacy and the public understanding of science (PUS) have successfully been developed and implemented. The above does not imply these metrics do not exist or have not been proposed, however as a result of ongoing debates, (addressed previously) general consensus does not exist as to the applicability of many PUS indicators. Elkana *et al* discuss the various definitions of science indicators and propose the following definition: *science indicators are measures of changes in aspects of science* [over time] (Elkana et al, 1978 - page 3).They propose this definition as an *opening to the discussion on science indicators* rather than a definitive demarcation of the practice, as many different types of science indicators exist. The focus on theory-laden normative measures is considered limiting by Elkana *et al* who propose that science as a cultural model of society should recognise the social embeddedness of the enterprise and aim toward further study of these interrelations. The proposal then is one of "*disciplined eclecticism, one in which the various opinions, views and value of the known elements within science indicator studies are adapted and absorbed toward greater understanding, in the absence of an overarching theory of scientific change in the foreseeable future*' (Elkana *et al*, 1978). Barre adopts a similar position, stating that [indicators] being debatable is not a limitation to the study and production of S&T indicators, but the very essence of the contribution of indicators to decision-making processes (Barre, 2010). He goes further to state that indicators can be developed to measure activities at varying levels within the system (*micro, meso* and *macro*) as well as dealing with varying *objects* and *contexts* of STI policy and decision-making processes.

In this light, results from surveys of public understanding of science generally produce a limited number of statistics and indicators (Bauer and Falade, 2014). Measures of scientific knowledge usually include statistics of knowledge of basic scientific facts, processes and contextual or application of scientific learnings to daily life. Results of scientific knowledge measures are most often disaggregated by age, gender, education level and geographic location (or similar demographic segmentation). These knowledge measures provide some insight into the level of scientific knowledge within the public[41] under investigation, and stem from the often quoted axiom, *'the more they know the more they will love it* [science]*'*.

Measurements of attitude to science had emerged under the *public understanding of science* paradigm, with questions (among others) related to the impact of *scientific knowledge* on a*ttitudes to science* (Bauer, 2009). The most commonly used metric to measure attitudes in these surveys is the *Index of Promise and Reservation* (Blankley and Arnold, 2001; Reddy *et al*, 2009). The index is constructed using seven (7) statements, split by 4 statements of scientific *promise* and three (3)

[41] While these generally refer to the general public, at times surveys have investigated specific publics and limited findings to the community in question.

statements of scientific *reservation*. Promise statements are generally positive and related to perceived benefits of science, while reservation items assess attitudes to science that involve risk, public concerns and fear (Reddy *et al*, 2013). The index is constructed by tabulating the results for each of the indices such that an overall ratio is obtained for the scores achieved on each of the scientific promise and the scientific reservation indices. Within this ratio scores range between -1.0 and +1.0 - wherein a higher positive score indicates a generally more positive attitude to science (Reddy *et al*, 2013).

Additional statistics of PUS data include items identifying the key sources of *scientific information* within the public sphere. These generally comprise of lists of information sources, including television, radio, newspapers, libraries, scientific publications, and more recently (various elements of) the internet[42]. Data on information sources are descriptive, presented in tabular form and often undergoing minimal statistical manipulation, limited to sums and averages and at times stratification along selected demographic and related criteria. Similarly, *levels of interest in science* is another descriptive measure that (most often) is self-reported by respondents using a list of scientific research areas and asking respondents to indicate a level of interest for each area on a 5-point scale ranging from *very interested* to *not at all interested*. Results are reported in tabular form or with the use of a bar-chart indicating scales of interest per research field. Selected surveys have also included questions on *public engagement in science dialogue* (NSF, 2014). These questions look at the level of public participation in science learning areas such as exhib*itions, lectures, museums, science parks, zoo's* and *botanical garden*s. Many of these questions are used to develop basic statistics on public-science interaction points, however very few venture to produce (publically available) detailed results based on demographic stratification and related analysis that would prove beneficial to the public and inform more effective science policy. The most recent survey conducted in South Africa (see Reddy *et al*, 2013) limited its analysis to attitudinal areas (*Index of Promise and Reservation*) and international comparison, and have yet to conduct detailed demographic and related analysis[43].

More recently research into the development of indicators and indicator systems for the measurement of public understanding of science began to emerge (Shukla and Bauer, 2009). The practice of *science culture* research generally includes elements of the scientific literacy and public understanding of science paradigms. However in addition to these, a defined focus on *science in a social context* is established as a foundational element. This includes the values and support for science, science as part of culture and the process and products of linking science with society and the public (Song *et al*, 2011). Science Culture is, as Scientific Literacy and Public Understanding of

[42] Including news websites, blogs, social media (Twitter, Facebook), institutional / corporate websites etc.

[43] Planned work on this dataset is noted, however detailed analysis has not yet been made publically available

Science, ill-defined, but has attracted much interest in numerous geopolitical settings due to its multiple level indicator systems as well as its capability to account for institutional science as well as public understanding and scientific literacy areas within society (Song *et al*, 2008). Song and colleagues devised an indicator system (*Science Culture Indicator for Individuals* - SCI-I) that includes both the *Individual* and the *Social* dimensions of science measurement. Each dimension is then further divided into the *potential* and *practiced* dimensions. The sub-divisions thereby produce indicators for *Individual-Potential, Individual-Practice, Social-Potential* and *Social-Practice* measurement areas. These areas include public scientific literacy as well as the infrastructural environment of the national scientific system, and are again subdivided to individual indicator elements (in Korea). The research team later developed a similar indicator system (*Science Culture Indicator for Society* - SCI-S) to measure science culture in different cities and municipalities in Korea (Song *et al*, 2011).

Research by Grupp and Mogee (2004) has also demonstrated the application of a new index and the development of composite indicators for the measurement of S&T policy with a particular emphasis on the European region. Testing of these indicator models in various European countries, applying minor variations in methodology (adjustment of weights, indicator selection), reflect inconsistencies and reveals room for manipulation and misuse. The authors conclude that refinement is required, but furthermore a multi-dimensional approach must be adopted to produce the required level of data the research requires to forge ahead .Likewise, Archibugi (2004) published work on the development of a new indicator for *technological capabilities* (*ArCo*) in developing and developed countries. While this related more to a measurement of technology, than to scientific literacy/public understanding of science, it remains valuable toward the development of indicators within the current research project domain area. The *ArCo* indicator system adopts a multi-dimensional approach toward measurement of technological capabilities, with eight (8) sub-indices related to research & technological infrastructure as well as output measures (journals and patents). While it takes into account national tertiary science and engineering enrolment as well as literacy and similar STI indicators, it does not specify *science literacy,* but rather, *general literacy* that also involves applied technological competencies (Archibugi, 2004). The *ArCo* indicator system delivers a means to measure and compare national systems across territories with greater ease of comparability, but with its limited focus on science culture and the public understanding of science, its direct value and applicability to this research project is limited.

The recognition that the current and future momentum of scientific progress remains as a result of social construction, relying on a diverse community of direct and indirect role players, underpins the social elements within which the scientific enterprise is seated (Snow, 1959). Historically, the objectivity of all fields of science has been its preferred output format; however the failure to recognise the social envelope within which much of this objectivity is derived must be understood toward effective planning, funding and applicability of technologies and advances that are derived within the scientific community. While it is apparent that the social milieu greatly influences the environment within which effective science may be practiced, a more inclusive appreciation of the subjective human influence must become a requirement as each is complementary to the other– a *sine qua non* for social and knowledge development within a society. As Shukla and Bauer put it, PUS indicators and traditional science indicators *"are two sides of the same coin of science culture…"* (2009, p. 37). As such, Shukla and Bauer (2009) developed a cultural indicator called the *Science Culture Index,* which combines the influence and value of two (2) data streams to produce a composite indicator of *Science Culture*. The *Science Culture Index* (SCI) uses traditional science, technology and innovation indicators (STI) such as R&D expenditure, publications, researcher headcounts, graduates, and local infrastructure and combines them with traditional PUS statistics to produce a composite indicator of Science Culture. Shukla and Bauer (2009) note the importance of science culture[44] as an essential asset within the science system, alongside other objective factors such as funding, infrastructure and human resources, however remains less tangible in its manifestation.

These new measures of science and the advances they bring to the study of the public understanding of science by *de-emphasising the importance of rank ordering people by knowledge gradients* and instead focusing on science as the oxygen of society, infiltrates every aspect and dimension of the social world (Bauer and Falade, 2014). The next section will unpack the socio-cultural dimensions of science in the South African context.

4.1.3 INDICATOR DEVELOPMENT for the SOUTH AFRICAN CONTEXT

South Africa is a multi-dimensional society in most every aspect of consideration (Goolam, 2001; Aiwuyor, 2011). Nine (9) provinces, 11 official languages, numerous cultural and religious groups, and the many legacy impacts of apartheid have stratified the South Africa population into multiple and often non-mutually-exclusive public**S** (see discussion in chapter 1). The multiplicity of public classifications could be explained within the varying stratification means used, through race, class, religion, financial resources, location, language, education and or other social classifications. Further to this, individuals may simultaneously be segmented into varying notions of the public**S**, deepening the critical difficulties experienced in developing applicable and appropriate indicators within areas

[44] The social envelope of the scientific enterprise

of measurement. With respect to areas of research and measurement, this multidimensionality further emphasises the difficulty in trying to develop measures that also take into account the variability related to income inequality, access to education, social and health services as well as other interrelated and co-dependent variables at play in the contemporary South African *general public* (Laugksch, 1996).

South Africa's three major economic hubs remain Gauteng, the Western Cape and KwaZulu-Natal. However, within these provinces, the major metros (Cape Town, Johannesburg-Pretoria and Durban) offer the strongest economic performance and employment opportunities to individuals suitably experienced and qualified. Outside of these geographical areas, economic production, service delivery and opportunities for gainful employment, while present, decreases as one moves further away from the major metropolitan settlements. This produces a non-urban population that is predominantly employed in production, agriculture and unskilled-manufacturing. As younger populations leave school[45], and begin to enter the workforce, many do not have the opportunities of further education and this, combined with increasing unemployment and the related social concerns, further polarises the population at various levels. Similarly, as populations start to migrate toward urban areas, the size of the rural population is decreasing, constituting closer to one-third of South Africa's population where in the past it was significantly higher (48% in 1990). As many of these unskilled or inexperienced newly-urbanised populations continue to move to the major cities, attention must be focused on growing the absorptive capacity as the numbers of job seekers and graduates continue to exert pressure on the social and economic systems. Increasing economic activity, promoting entrepreneurship, employment, training opportunities, infrastructure and services are all key elements that must be championed in creating a favourable socio-economic environment for future growth and development across South Africa. Many of these interrelated activities share an unparalleled link with advances in science and technology-derived solutions that must be converged toward enhancing the social and environmental realities in this country. It follows, then, that to address many of these matters, effective measurement and the adoption of an integrated, multi-level approach toward measurement and policy implementation is required within South Africa.

In developing an understanding of the many South African public**S**, salient elements to consider include the impact of socio-demographic variables; public knowledge, application and social value invested in S&T areas; the availability of data streams towards developing statistics and indicators as

[45] At grade 12 or earlier, as is common

well as the appropriate policy environment required toward fostering a holistic awareness of the South African social envelope.

As a direct result of the legacy impacts of apartheid, numerous social factors and inequalities must be considered toward the creation of receptive social environments for the application of measurement instruments. The social gaps that exist as a result of varying access to education, social services, housing and employment all contribute to a perpetuated inequality within South African society. Many of these inequalities are still apparent on racial[46], social, provincial and economic strata. Looking at the results relating to education in the 2011 National Census (South Africa) these realities are clearly visible in chart 4.1 below (StatSA, 2012). While significant strides have been made in the preceding 20 years to address critical areas of education in South Africa, as a result of interrelated social and economic factors, these successes are not visible in all nine provinces.

The gains in this area vary considerably by each of the nine provinces in South Africa, with six provinces reporting more than 10% of its population aged 20 years and older (pre-*born free*[47]) as having no formal education. This far-reaching factor undermines the individual and collective potential for future tertiary/continuing education, gainful employment and, in certain areas, meaningful democratic participation and quality of life.

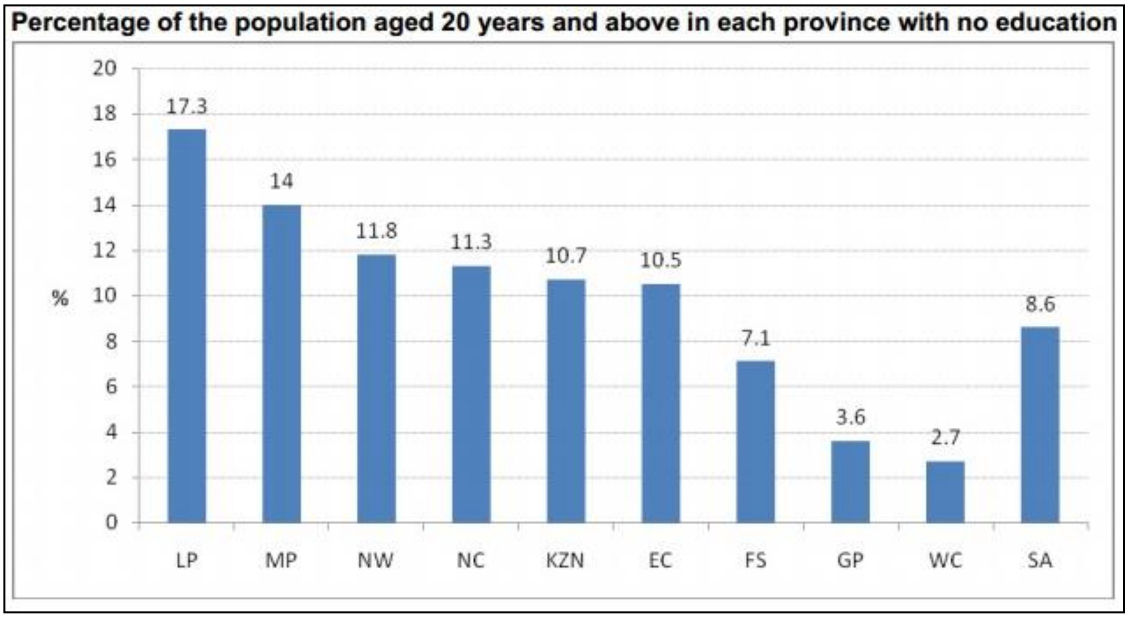


Chart 4.1: Population 20 years and above with no formal education (Source: StatSA, 2012 page: 50)

Due to pre-1994 educational policies in South Africa, age plays a key factor as a vast number of individuals aged 20 years and older (pre-*born free*) have not benefited from the massive investment

[46] Not by design, as it was during apartheid, but as a legacy social impact that is slowly being addressed 20 years later in the democratic South Africa
[47] *Born-free* – a South African term used to denote individuals born post-apartheid in 1994.

in basic and higher education over the last 20 years. While adult and continuing education is available, few individuals benefit as a result of the associated costs or inaccessibility of these services for a variety of reasons[48]. In an economy of ever-increasing reliance on S&T derived solutions, this creates another polarising factor, wherein younger people are at a significant advantage compared to their senior community members as a result of a *knowledge gap* within society. Related to this, but as a broader concept that permeates all segments of society, is the social value attributed to science and technology within South Africa's publicS. The appreciation by the collective public[49] of the contribution of science to the economy and society must be shared and valued by all citizens. This would ensure effective knowledge seeking and educational outcomes, which would in turn build stronger economic systems and produce better products. Moreover this would lead to the development of the essential human capital (beyond those already in science careers) to build the required social trust and support needed for greater investment and value of science in society.

A further consideration is the fact that, as in many developing nations, South Africa has a valuable traditional/indigenous knowledge system that supports societies and development in avenues different[50] from traditional S&T systems. The value and contribution of these systems must be taken into account, beyond the "accepted textbook" notions of English-dominated-western scientific culture presenting a discussion that is particularly complex and has developed a specialised area of research within the scientific literacy and PUS domain (see: Zhang & Zhang, 1993). Similar concerns have been raised across many non-English speaking nations, where language and culture all play major roles in the different populations' notions of science as well as levels of understanding; communication and support for science across the developing world (see Lee, 2001).

The production of statistics and indicators requires the development and access to various data streams. While the production of nationally representative research data is costly and time consuming and requires specialised skills to produce high quality datasets, very few of these national datasets are available in South Africa for a variety of reasons. In South Africa, data is produced by a number of stakeholders including government departments and agencies, universities, research institutes, centres of excellence, science councils, industry and private sector research. In the area of science measurement, a number of nationally representative and official surveys have been produced for some time, including the numerous outputs by StatSA, the DST, the HSRC, the Universities (CREST, IERI etc.) and the private sector. Many of these datasets are not publically available and none have been harmonised in meaningful ways so as to derive extended insight into

[48] As a result of a lack of basic literacy, foundational learnings or time / cost / employment factors
[49] Scientists and science and technology graduates / employees being members of this general citizenry
[50] Though not entirely dissimilar

trends and emerging areas of public understanding of science. Within ambitious long-term, multi-dimensional projects, such as the *measurement of public understanding of science*, significant access, integration and the establishment of new data streams must be put on the policy agenda toward efficient research design. This is ultimately directed at effective, culturally sensitive and inclusive intervention strategies within specifically identified segments of the general public. Much of this idealised research environment is not yet a reality in the area of science policy research in South Africa. A greater sustained effort must be directed toward understanding the social context of science, its communication, understanding and promotion; to develop a broader South African public that is attentive to matters relating to science and technology.

4.1.4 TOWARD THE PRODUCTION of PUBLIC UNDERSTANDING of SCIENCE INDICATORS

The previous section on *statistics of scientific literacy and the public understanding of science* (PUS) explored the evolution of measurement and the development of statistics and indicators within the area of scientific literacy and PUS. The question design and areas of focus demonstrated initially by the NSF and the *Eurobarometer* surveys have been adopted in a number of settings over the last 30 years (Bauer *et al*, 2007), allowing far greater international comparison than in the past. Recent interest, particularly in the developing world, related to measurement modalities convergent with the domestic *science culture* context have developed a series of models and indicator systems that may, in the long term, inform measurement techniques going forward (Chan, 2009; Sun, 2010).

The OECD defines a science indicator as *'…a series of data which measures and reflects the science and technology endeavours of a country, demonstrates its strengths and weaknesses, and follows its changing character notably with the aim of providing early warning of events and trends which might impair its capability to meet the country's needs*' (OECD, 1976; Godin, 2001). Similar to the earlier discussed definition employed by Elkana *et al* (1978), the key element represented in both definitions is that of *observation of changes in the data over time*. This *time element* necessitates a baseline measure, followed by regular measurements; which will position the data to be seated in time, and the indicators as tracking the changes in these data over multiple iterations with a suitably representative sample of survey participants.

In South Africa however, too few appropriately designed surveys[51], both in terms of size and scope, are conducted (see Pouris, 1991 & 1993; Laugksch, 1996). Furthermore, within the surveys conducted in South Africa over the last 25 years, taking the previous point into account, surveys of the *general* public understanding of science are irregularly conducted in South Africa (see: HSRC,

[51] In terms of both the size and scope of the surveys completed relating to the design of the survey, sample size and coverage as well as limited population of measurement (students or particular race groups only)

1995, 1999; Blankley and Arnold, 2001; Reddy *et al*, 2009). While there have been more than 20 empirical[52] studies conducted in South Africa since 1991, only six (6) of these studies sufficiently produced data from a nationally representative sample relating to the *general* public understanding of science, rather than surveys investigating *specific* interest areas (see TIMSS, 1995,1999,2003; SASAS, 2004 – *Biotechnology*; SASAS, 2007 – *Climate Change*). As a result, detailed awareness on the contemporary *South African public understanding of science* is inadequate within these discussions. While the recent work of the HSRC has since 2009 intermittently undertaken studies on the public understanding of science, a more frequent series of measurements needs to be established, to complement existing products and datasets under the various STI role players in South Africa.

As a consequence of the lack of baseline data, the development of more complex data outputs discussed in this chapter would be inappropriate under the current dearth of information relating to the South African public understanding of science. The current research therefore aims to develop a question set that provides an assessment of the overall South African public understanding of science. An additional aim of this study is the production of a set of indicators to allow for repeated measures of these factors over time. The multidimensional nature of the South African public with respect to demographic classification and its varying degrees of influence within the measurement domain (discussed earlier) will furthermore be investigated. This noted socio-cultural complexity must first be understood prior to exploring the development of *cultural models* of the South African public understanding of science. While it is noted that the multiple levels of the South African publicS will at a future point be viewed from within a multidimensional model, this initial research attempt aims to produce a baseline measure and predictive model to ascertain the *general* South African public understanding of science.

The study includes questions previously adopted and further adapted to be more suitable to the local context. These questions aim to assess *scientific knowledge*, *interest*, *sources of information*, *public attitude* and *public engagement* with science activities. Key here is the identification and adaptation of suitable questions which include appropriate *science subject areas* that are of most value to the South African general public within a particular social context.

4.1.5 THE SIX ELEMENTS of the SOUTH AFRICAN PUBLIC UNDERSTANDING of SCIENCE

Miller's dimensions of scientific literacy (1987, 2004) have formed the foundation of many surveys and, particularly in the USA, continue to inform the large NSF indicator-producing series. Having been adapted and expanded upon by later scholars, it has been applied beyond scientific literacy,

[52] See table 3.8 in Chapter 3 for list of empirical works conducted in South Africa

and also within surveys of the *public understanding of science* research paradigm (see: *Eurobarometer* series). The underlying concerns within each research paradigm relates to *public knowledge*, *level of interests, access to information, public attitudes and public participation*. These elements of the South African public understanding of science, when viewed concurrently, represents a viable model for the construction of a *scientific knowledge ecosystem* within which the individual, as the basic unit of the 'general public' exists (see: Bronfenbrenner's' *Ecological Systems Theory)*.

Within this theoretical framework, personal development within a specific area is influenced by all factors in the surrounding environment, at five (5) levels of varying interaction. These levels include *microsystem*, *mesosystem*, *exosystem*, *macrosystem* and *chronosystem*. Each of these levels has varying degrees of direct interaction with the individual and with each respective system element, which influences holistic development over time (see figure 4.2).

Figure 4.2: The 6 elements of the South African Public Understanding of Science (SAPUS) in the social context

With respect to the public understanding of science, such an ecological systems approach seats the individual, as the basic unit of the public, within a social context. This view directs the focus of individual, and at the aggregate level, the public understanding of science as a direct consequence of the social and environmental landscape within which individuals encounter this domain. In a country like South Africa, with its eclectic mix of demographic sub-populations, languages, cultural and religious influences, the impact of emerging from a segregated past cannot be under-evaluated with respect to its impact, in turn, on the public relationship with science.

The influence of sociocultural stimuli within these demographic stratifications remains a key aspect toward building the exploration of the South African public understanding of science from the baseline. Ultimately, the impact the major demographic variables on the general South African public understanding will inform the development of future models and intervention strategies (see figure 4.3).

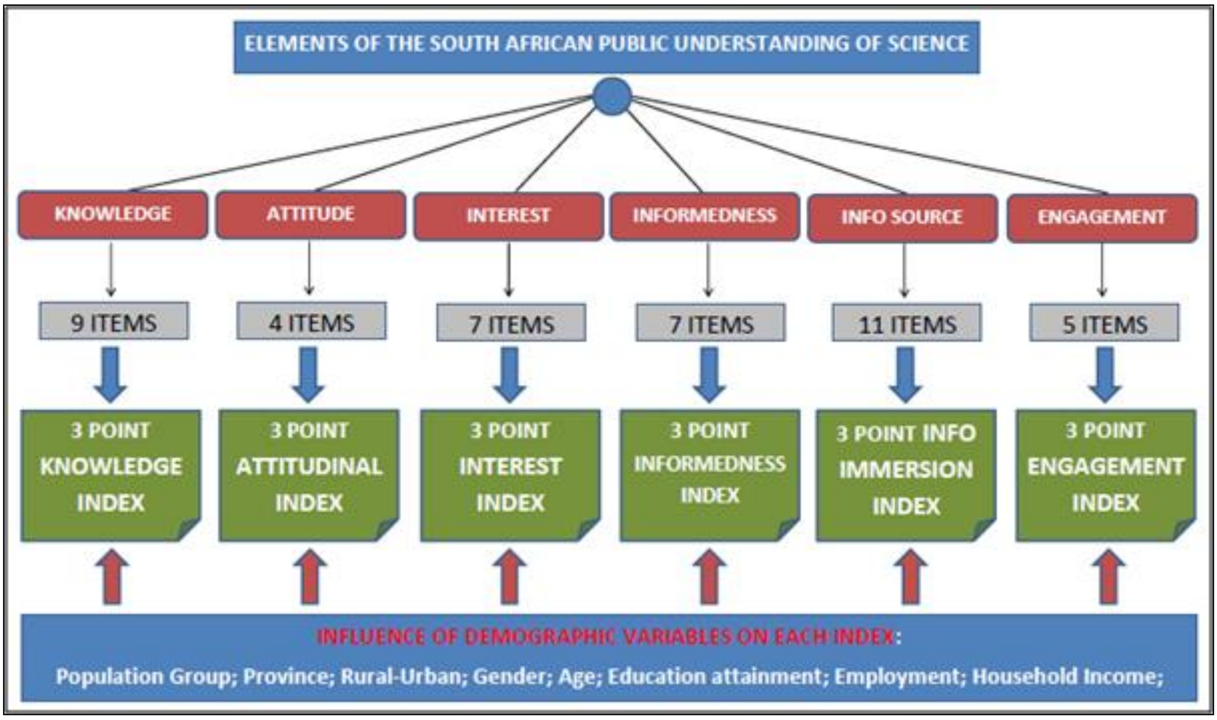


Figure 4.3: Conceptual framework for investigating the South African Public Understanding of Science

Each of these six elements have been operationalised using question designs reflective of the large surveys of PUS and *scientific literacy* (see: NSF / *EuroBarometer*), however specifically adapted[53] to the South African context. *Scientific knowledge* questions were based on a combination of *general knowledge*[54] science concepts and issues identified as specifically important within contemporary South African life. The *Science Knowledge* assessment includes 9 statements requiring a *True*, *False* or *Don't Know* response (e.g. *Lightning never strikes the same place twice*).

Attitudes to science are measured using two indices: *Index of Scientific Promise* and the *Index of Scientific Reservation* (Shukla and Bauer, 2009). The indices combined consisted of four (4) questions

[53] Where required, specific *content*, scientific *subjects* and *information sources* that are most relevant to the South African context will be integrated.
[54] It is recognised that a higher illiteracy rate and a higher number school dropouts in SA may challenge the assumptions of adopting *general knowledge* science concepts – however as a competency assessment it should be acceptable for use.

relating to specific positive or negative attitudes toward science wherein respondents are provided *Agree*, *Disagree* or *Don't Know* response options. The calculation procedure of the *Index of Promise and Reservation* will be discussed in a later section, however will not deviate from the accepted practices (see: Blankley and Arnold, 1999; Reddy *et al*, 2009; 2013).

Interest in science was operationalised assessing 7 self-reported levels of *interest* in topical areas of science. The levels of interest ranged from *Interested* to *Not Interested* and included a *Don't Know* response option. These science areas were determined through appropriate study of information sources in South Africa (e.g.: media analysis etc.) with the same focus on localisation as with the *knowledge* measures. The dimension related to *Informedness* in science was gauged in similar ways to the *interest* items, with related design, construction, response options and analysis methodology.

An assessment of the most frequently accessed *science information sources* among the South African public was designed adopting 11 key information channels and requesting respondents to indicate the frequency of encountering science information within each of the items listed. The last element was designed to assess the level of involvement in *science engagement activities* within the preceding 12 months. This included a list of the key science engagement activities and locations in South Africa where individuals may encounter information and dialogue within any branch of science. These engagement activities included visits to *public libraries*, *zoos, museums, science centres, public talks* and *festivals*.

These six elements of the South African public understanding of science were cross-analysed with the corresponding demographic data toward the development of indicators of the South African public understanding of science. As a result of its design and implementation, the survey yielded a nationally representative sample, ensuring that these indicators could be generated at both national and provincial level and according to gender, age, location and other socio-economic stratification variables. The value of this proposal lies within its repeatability and, ultimately, its capability to produce indicators at multiple levels toward providing locally relevant information that could enhance intervention strategies.

The methods described above are discussed in greater detail below, where specific design, testing, quality assurance and reliability assessment procedures are presented.

4.2 DEVELOPMENT of the 2015 *KHAYABUS* MODULE on PUBLIC UNDERSTANDING of SCIENCE

The research procedures of this study are described in this subsection and will detail the purpose, design, development, quality assurance and fieldwork practices employed in the data collection phase. This section covers all operational aspects of the project relating to the fieldwork preparations, procedures and implementation of the survey module in the Khayabus survey wave 2 of 2015. The following chapter subsection will briefly discuss the data analysis procedures applied in the application of the *Khayabus* survey results toward the development of indicators related analysis to be presented in chapters five and six.

4.2.1 Why create new test items? The purpose of the Khayabus instrument module

To date, most all of the surveys on scientific literacy and the public understanding of science in South Africa have been operationalised through the adoption of instruments, in full or in part stemming from international studies such as the NSF or the Eurobarometer survey series. In other developing world settings, surveys of this type have similarly incorporated well established test items to retain a sense of international comparability and standardisation (see chapter 3). As previously discussed, many of these test items, while considered *generic* and acceptable in terms of their scientific and factual accuracy, have been discussed in multiple settings with particular reference to the concept of cultural distance of knowledge constructs (Raza *et al*, 2002), language and related social factors (Zhang and Zhang, 1993). Linked to this is the broad content area of the scientific enterprise and its relevance to the daily lives of ordinary citizens. As a result, items historically selected have been rooted in selected scientific areas, such as *physical science* or *human biology* (*the earth revolves around the sun* or *antibiotics do not kill viruses*), rather than emerging fields of scientific knowledge or broader reference areas.

Within the South African setting, among the locally developed test items, Laugksch (1996) developed 472 scientific literacy test items that covered Miller's three consecutive dimensions of scientific literacy. With a focus on educational outcomes and scientific literacy, Laugksch generated his items using the expected levels of knowledge high school-leaving learners are required to display upon entering tertiary education institutions. The methods employed by Laugksch (see chapter 3) reviewed the *Project 2061* publication – *Science for All Americans* – and adopted selected text from this publication to develop a pool of test items (Laugksch, 1996, 2000). These items were then assessed by experts within the scientific domain in South Africa and a final pool of 240 key items was produced. Following rigorous linguistic and technical quality assurance procedures, a final *Test of Basic Scientific Literacy* (TBSL) was produced. The TBSL contained 110-items across three (3) sections: *the nature of science, science content knowledge* and *impact of science on society*. The pool of 472 test items developed by Laugksch provides a valuable base toward the development of new survey instruments. As a result of the methods employed in their development, the meticulous quality and technical language assurance procedures as well as the foundational grounding of the items within the theoretical literature, this pool of test items opens a wider stream of science subject focus areas, specific to the South African setting. However, the Laugksch test items were developed specifically to measure *scientific literacy of first-time entering university students in South Africa* based on the expected outcomes of an American education system and as a result were not considered suitable for complete adoption in the present study. Laugkschs' pool of test items was however used to inform the selection and development of included test items (discussed in a later section).

The development of the survey module for this research adopted as its base requirement an instrument that is able to access the six identified elements of the public understanding of science. The instrument maintained the requirement to remain linguistically-relative and appropriate to the South African setting as well as retaining a degree of international comparability. Noting the earlier discussed social and multicultural nature of the South African publicS, the items selected were refined toward the development of an instrument that was applicable to a broad cross-section of the South African publicS. The instrument was developed to measure the public understanding and engagement with science in South Africa and includes six question-sets all relating to each of the elements of the public understanding of science. These elements are operationalised through the use of a questionnaire informed by previous question banks[55], however selected items or item-text were suitably adapted or replaced toward an appropriate localisation of the survey-item content.

<u>The IPSOS Khayabus Survey[56]</u>

To accurately and cost-effectively measure large numbers of individuals with respect to the subject matter, the approach of this study was to design a module for inclusion in an omnibus survey intended to produce a nationally representative sample of South Africans aged 18 years and older. The specific survey identified for the operationalisation of this module was the 2015 wave 2 of the *Khayabus survey* product from international research provider IPSOS[57] under their *Public Affairs: Social Research* division. The survey runs in 2 waves annually, covering a total of approximately[58] 4 000 respondents in each wave from all geographical areas, provinces, race groups, genders as well as religious and economic population groups across South Africa.

55 See Bauer, Allum& Miller, 2007; Shukla & Bauer, 2009; Laugksch, 1996

56 The initial proposal planned to use a different omnibus survey, however as a result of cost considerations, The IPSOS Khayabus Survey was considered a more suitable product to use.

57 See http://www.ipsos.co.za/_layouts/15/start.aspx#/SitePages/Our%20Omnibus.aspx for more information

58 Exact numbers do differ slightly across survey waves and survey years.

IPSOS retains a national team of in-house, dedicated, full-time professional fieldworkers that are entrusted to carry out the fieldwork on the Khayabus survey series. All fieldworkers attended mandatory briefing sessions and a dedicated training session on this specific survey module, to ensure accurate operationalisation of the survey instrument. Weekly telephonic contact sessions with the accounts manager at IPSOS as well as with the field force team leaders ensured consistency in the application of this module during the data collection period.

The Khayabus survey is conducted as a face-to-face survey at the respondent's home using Computer Assisted Personal Interviewing technology (CAPI). The CAPI system uses mobile technology to capture results of fieldwork directly to a tablet or laptop and remotely upload the data to a database managed by the IPSOS team. This data is then cleaned and processed toward producing the final dataset. Overall, the survey is designed to yield a nationally representative sample of South Africans 15 years and older[59], with a margin of error of 1.63%[60]. The sample is designed to include both urban and rural respondents. The metropolitan sample covered the major metros in Johannesburg; Pretoria; Durban; Pietermaritzburg; Bloemfontein; Port Elizabeth; East London and Cape Town. The non-metropolitan sample included areas from all nine provinces, including deep-rural areas. The survey is designed to ensure that local customs negotiated access, language and related key success factors are in place prior to fieldwork commencement.

All questionnaires are translated from English into Afrikaans, Zulu, Xhosa, Setswana, Northern Sotho, and Southern Sotho by professional translators and are available in the field as per the respondent's preference. Fieldworkers proficient within regional language groupings were dispatched to ensure that the data collection was consistent with the language of the instrument used. During the data cleaning, the *random iterative method* (RIM) weighting was applied to account for parameters within the South African national population and ensure proportionality across the many variables.

In order to measure the six elements discussed earlier, questions were developed for each element, measuring *scientific* k*nowledge*, *attitude*, *interest*, *informedness* and involvement in *engagement* a*ctivities*. Caution was applied to ensure the balance between a degree of international comparability while simultaneously localising the questionnaire content sufficiently so as to accurately measure the public understanding within the social context of science in South Africa. Traditional questionnaire conceptualisation, construction, design and item selection procedures as described by Blankley & Arnold (2001), Bauer & Shukla (2009) and Reddy *et al*, (2010) were adopted

59 For the *Public Understanding of Science* module, minors younger than 18 years old were excluded.
60 This will be discussed in greater detail in the next section

in the design of the layout for the various elements of measurement. Each element will be discussed individually in the following section.

4.2.2 Questionnaire Design and Item Generation

Specific question designs were adapted from the standard NSF and *EuroBarometer* studies (and replicated by others[61]). However, the selection of specific items and item-text was informed by various background research activities toward the production of the final questions in the module. The basic questionnaire design framework is presented below in table 4.2 and each section will be discussed in turn through the following subsection:

Question Section	Response type
SECTION A: Scientific knowledge	**True, False**; 3 Point Closed-Ended
SECTION B: Attitude to science	**Level of Agreement**; 6 Point Closed-Ended
SECTION C: Interest in science	**Level of Interest**; 4 Point Closed-Ended
SECTION D: Informedness about science	**Level of Informedness**; 4 Point Closed-Ended
SECTION E: Information sources about science	**Frequency of Exposure**; 3 Point Closed-Ended
SECTION F: Participation in science engagement activities	**Yes, No**; 2 Point Closed-Ended

Table 4.2: Basic Structure Of The PUS Khayabus Survey Module

Section A of the questionnaire relates to the question-set measuring the *science knowledge* element of the public understanding of science. Chapter 3 provides an extensive review of the many domestic and international empirical studies of scientific literacy and the public understanding of science. A key finding in reviewing the research instruments employed in these studies, from both the developed and developing world, highlights an implied *natural / physical science bias* within the item selection for the measurement of the *scientific knowledge*. Accounting for this, the design of the knowledge question-set in the present study deliberately adopted the approach to include as many fields of science as it could beyond (and including) the physical and natural sciences[62]. As a result of the above, this study therefore defines *science* as *all fields of systematic enquiry and codification of natural and human knowledge.* Wilson (1998) offers a similarly inclusive definition of science, '*… the organized, systematic enterprise that gathers knowledge about the world [and humanity] and condenses the knowledge into testable laws and principles*'. He goes further to state that this definition includes multiple fields of natural science, social science, the humanities and interdisciplinary fields of enquiry. To this end the present study broadened the *science knowledge items* to include multiple fields of science relevant to daily life in contemporary South Africa.

[61] See: Chapter 3

[62] See below section on the selection of *knowledge categories* for the *knowledge* question-set

The question-set investigating *scientific knowledge* comprises nine (9) statements requiring respondents to indicate a single *True* or *False* response. While a third, *Don't Know* option is provided, it is not read out to respondents[63].

The number of statements in these knowledge assessment tests has differed in various studies; more interestingly, the subject areas covered similarly adopt a general pattern of science subject areas. As an example, in South Africa, Blankley & Arnold in 2001 included five items in this question, with subjects ranging from biology, physics, astronomy, anthropology and medical science. Shukla & Bauer (2009), in comparing Indian and European data, included items from varied science subject areas: medical (x 2), astronomy (x 2), geology (x 2), biology, physics and anthropology. Similarly, Reddy *et al* (2010) have, in their SASAS (*South African Social Attitudes Survey*) module, adopted six knowledge items that included subject area categories from: medical science, astronomy, geology, biology, physics and anthropology. In reviewing these subject areas, and comparing these against data for South Africans' self-reported interests in scientific areas[64] a disconnect emerged between the assessment of *knowledge areas*, and the actual self-reported *scientific interest areas* of the South African public.

In order to align the *knowledge* assessment with actual South African self-reported science *interest* areas, item-subject categories[65] were constructed to match these *interest areas*. In reviewing responses to questions on *interest in science* from earlier SASAS studies, item-subject categories were identified for the *knowledge* question. This approach was adopted in order to ensure that *knowledge* assessment is in line with *actual* South African public *interest* in science, toward a more representative assessment of scientific knowledge within the South African publics. *Interest areas* and item-subject categories were then assessed for selected surveys of public understanding of science for the period 2001 – 2010. The frequency of item-subject categories and *interest areas* in these studies informed the final selection of the subject categories to be used in the present study. The subject categories were then later populated with item-text relevant to each of the science subjects areas selected (see figure 4.4).

[63] Dolnicar & Rossiter (2009) note the importance of the *don't know* option in opinion surveys, particularly the non-verbalised D/K options produces more reliable data than excluding the D/K option from the response group entirely.
[64] Most recent see Reddy *et al* (2010)
[65] Actual items will be discussed later – here the author refers only to science knowledge *subject categories*

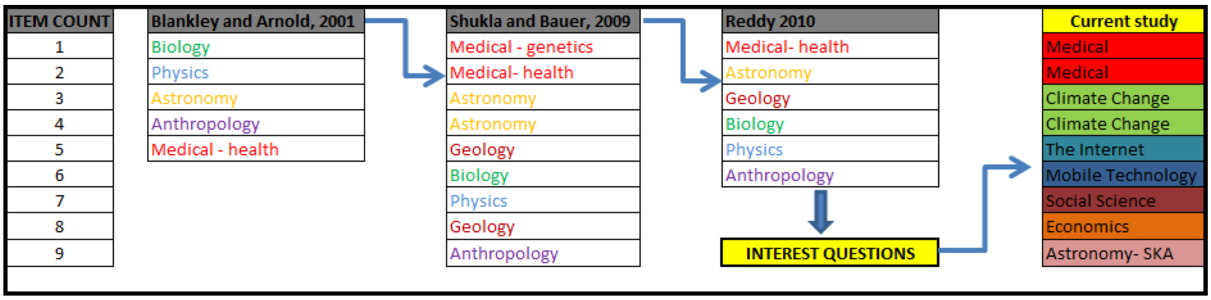


Figure 4.4: The development of Knowledge categories for inclusion in current study

The *science knowledge* subject area categories selected includes *physical science* – astronomy & earth science; *biology* - medical science; *social science* – economics, psychology & history as well as a *multidisciplinary* area of information & communication technology. These areas were selected to ensure coverage of the major fields of science as well as broadening the conceptual definition of science knowledge assessment within this research.

Actual survey item texts were then adopted adapted or developed specifically toward populating each of the previously identified knowledge subject areas. Key sources of item text were Pouris (1991, 1993), Blankley and Arnold (2001), the Laugksch (1996) pool of test items (discussed earlier), surveys by Shukla & Bauer (2009) as well as Reddy *et al* (2010) in addition to the NSF and *EuroBarometer* survey series items.

#	Source	Knowledge Area	Science Subject Area Category
1	RL	**Social and economic factors influence technological development within countries**	**SOCIAL SCIENCE - ECONOMICS**
2	RL	**The continents which we live on are continually moving due to forces deep within the Earth**	**PHYSICS - GEOLOGY**
3	RL	**Ideas about good mental health vary across different cultures**	**SOCIAL SCIENCE - PSYCHOLOGY**
4	RL	**The earth's climate has not changed over millions of years**	**EARTH SCIENCE - CLIMATE CHANGE**
5	SP	**The Internet is a global system of interconnected devices sharing information and content**	**MULTIDISCIPLINARY - ICT**
6	SP	**In the majority of cases, HIV causes AIDS in humans**	**BIOLOGY - MEDICAL**
7	SP	**The Square Kilometre Array Radio Telescope will be jointly hosted by South Africa and Australia**	**ASTRONOMY - SKA**
8	SP	**South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons**	**SOCIAL SCIENCE - HISTORY**
9	SP	**Schizophrenia is the same thing as Multiple Personality disorder**	**SOCIAL SCIENCE - PSYCHOLOGY**
10	SP	**Lightning never strikes the same place twice**	**PHYSICS - ELECTRICITY**
11	SP	**The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life**	**ASTRONOMY - SKA**
12	SP	**The price of petrol in South Africa is not influenced by the price of crude oil**	**SOCIAL SCIENCE - ECONOMICS**
13	SP/S&B	**The father carries the genetic material that will determine if a baby is a boy or a girl**	**BIOLOGY - MEDICAL**
14	SP/RL	**Mobile technology has no influence on the nature of human society**	**MULTIDISCIPLINARY - ICT**
15	SP/RL	**Human activity has no impact on the Earth's land, oceans and atmosphere**	**EARTH SCIENCE - CLIMATE CHANGE**

Table 4.3: Revised list of 15 potential knowledge area assessment items

A selection of 25 items from across all of the identified subject knowledge areas was then identified. After consultation with the project supervisor and other subject area experts[66], the list of potential items was reduced to 15 items (see table 4.3). From the above list of 15 potential test items, items 1-4 were *adopted* without edits from the previous work of Professor Laugksch (1996). Items 13-15 were *adapted* from those used in earlier studies; in particular, item 13 was adapted from Shukla and Bauer (2009), while items 14 and 15 are edited forms of items from Laugksch (1996). Items 5-12 were specifically developed for this study based on the particular knowledge subject area. Experts within relevant fields were consulted who verified the factual foundation of the statements created[67].

The revised list in table 4.4 was then further refined through a series of revisions[68] and field tests, while the reduced item selection emerged following the completion of the pilot testing phase[69] to yield a final selection of nine (9) items to be included in this section of the survey instrument. The science knowledge question-set in the current study is presented below:

Source	Knowledge Area	TRUE	FALSE	D/K
SP	In the majority of cases, HIV causes AIDS in humans	**1**	**2**	**8**
SP	Lightning never strikes the same place twice	**1**	**2**	**8**
SP	South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	**1**	**2**	**8**
RL	The continents which we live on are continually moving due to forces deep within the Earth	**1**	**2**	**8**
SP	The price of petrol in South Africa is NOT influenced by the price of crude oil	**1**	**2**	**8**
SP	Schizophrenia is the same as Multiple Personality Disorder	**1**	**2**	**8**
SP / S&B	The father carries the genetic material that will determine if a baby is a boy or a girl	**1**	**2**	**8**
RL	The earth's climate has NOT changed over millions of years	**1**	**2**	**8**
SP	The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	**1**	**2**	**8**

Table 4.4: Knowledge Assessment question from current 2015 Khayabus survey module

The above question contains nine (9) statements with reference to basic science knowledge areas that have been developed, adopted and (or) adapted into the identified *subject-interest categories* discussed previously. Of the nine (9) items, two (2) are adopted directly from the Laugksch pool of test items, while a single item was edited[70] from the question-set used by Shukla and Bauer (2009). The rest of the questions in the final selection were developed for this study by the author[71]. All the items were configured to be as simple as possible while addressing basic-science concepts applicable to daily life in South Africa. Many of these items have a high visibility in the media and have been

[66] Dr Moses Sithole at the HSRC and the written work of Professor Rudiger Laugksch at UCT
[67] Example: Item 11 was developed and confirmed by Mr Angus Flowers - Science Communications Officer at the SKA. Similarly Item 12 was developed and confirmed by a team of economists at the head office of a major fuel retailer
[68] With the research supervisor – Professor Mouton
[69] To be discussed in later section
[70] Original text: *the newborn baby is a boy or a girl depends on his / her father*. Revision by author for current study
[71] It must however be noted that the development may have been influenced partially by questions in earlier studies

carefully constructed to still allow for some international comparability while providing a more accurate assessment of South African public science knowledge in an expanded selection of science areas.

Section B includes questions investigating the element of *attitudes to science*. The *Index of Promise and Reservation* is a measurement that studies attitudes toward science. Respondents who have a strong belief in the *promise* of science are less likely to be wary about any potential adverse impacts of science. Conversely, respondents who report a greater association with the *reservation* statements are less likely to acknowledge potential benefits from scientific advances (Nisbet*et al*, 2002).

An assessment of empirical work conducted in South Africa and internationally over the last 20 years (see Chapter 3) has revealed that the basic design and layout of the index of *Promise* and *Reservation* have remained relatively unchanged within this time. To this end the questions adopted in the present study were minimally edited to conform to the statistical procedures required in later applications as well as to allow for international comparability.

	#	Attitudinal Statement	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	D/K
P	1	Science and technology are making our lives healthier, easier and more comfortable	1	2	3	4	5	8
R	2	It is not important for me to know about science in my daily life	1	2	3	4	5	8
P	3	Thanks to science and technology, there will be more opportunities for the future generation	1	2	3	4	5	8
R	4	The application of science and new technology makes our way of life change too fast	1	2	3	4	5	8

Table 4.5: Attitudinal Assessment question from current 2015 Khayabus survey module

While some attitude scales measuring scientific *Promise* and *Reservation* use seven (7) or more statements[72], the current study employs a version developed by Shukla and Bauer (2009) wherein attitudes to science are measured using four (4) items along a 5-point scale (and an unread Don't Know option). Bann and Schwerin (2004) developed short forms for the measurement of the public understanding of science, and in particular, the assessment of scientific *promise* and *reservation*. In their analysis[73] they compared the results from their investigations and report that traditional long forms (a 7-item version) do not differ significantly from the results achieved using the short forms (a

[72] See Reddy et al, 2010
[73] Using exploratory factor analysis, stepwise regression and correlation analysis

4- item version). As a result, the final Items and design of Section B: *attitude to science* question was adopted based on their finding (2004).

Among the four (4) questionnaire items selected, item 1 and item 3 each carry a message of *scientific promise* while item 2 and item 4 carry messages of *scientific reservation*. It is important to note that item 2 was replaced on the current item list as a result of the findings[74] during the review session as well as the pilot process. Attitudes were assessed using a 5-point scale of relative agreement to the statement, per question row. A *don't know* (D/K) option was provided, but not read out to the respondent.

Items 1 and Item 3 have been adopted directly from Shukla & Bauer's 2009 work, while item 2 was adapted from the findings of Bann and Schwerin (2004). The last question in the attitude section was adapted and edited from the original work of Shukla & Bauer (2009).

Section C of the survey module covers aspects related to specific *interest in science*. **Section D** (*Informedness)* adopts a parallel question construction and item text and will be addressed simultaneously. Items for the *Interest* (table 4.6) and *Informedness* (table 4.7) questions were derived from reviewing results from the most recent SASAS series data (Reddy *et al*, 2013). Of the total of seven (7) items, four (4) were included following a review of actual reported *interest* in science in earlier studies, while three (3) were developed by the author after reviewing subject area categories of science in the South African social context[75].

INTEREST AREA	VERY interested	MODERATELY interested	NO interest	D/K
Medical Science	1	2	3	8
Climate Change	1	2	3	8
Technology and the Internet	1	2	3	8
Politics	1	2	3	8
Economics	1	2	3	8
Astronomy	1	2	3	8
Energy	1	2	3	8

Table 4.6: Interest in scientific fields question from current 2015 Khayabus survey module

INFORMEDNESS AREA	VERY well informed	MODERATELY well informed	NOT well informed	D/K
Medical Science	1	2	3	8
Climate Change	1	2	3	8
Technology and the Internet	1	2	3	8
Politics	1	2	3	8
Economics	1	2	3	8
Astronomy	1	2	3	8
Energy	1	2	3	8

Table 4.7 Informedness about science question from current 2015 Khayabus survey module

[74] The original item "*Science is constantly changing and information is always updated*" was considered too neutral
[75] Areas of notable social interest and relevance from media review and review of previous empirical work

The questions above, that are related to the measurement elements of *Interest* and *Informedness,* have been constructed as a 7-item, 3-option, close-ended single-response question. Further to establishing the *interest* in science for a South African sample, it will then be possible to compare the self-reported *Informedness*[76] measures toward gaining further understanding of the conceptual distance between *interest* and *Informedness* in South Africa. The scientific categories selected represent a view of science in the widest possible frame. These include the *physical, natural* and the *social sciences*, including *politics* and *economics*. The categories by no means represent the most comprehensive list of scientific fields, but are related to the *subject knowledge* areas following a review of empirical work discussed earlier. Within this list, *astronomy* and *medical science* include elements related to space and medical innovation, while *climate change* relates to multiple fields of science studying climate change, human and natural processes. The category for *technology and the internet* includes all aspects of ICT advancement as well as technological innovation related to mobile technology, while *energy* includes all aspects related to the energy mix in contemporary South Africa. Respondents were asked to indicate their level of *interest* or *informedness* (in **Section D**) in each of the seven categories, using the 3-point scale.

Section E of the questionnaire focuses attention on the *sources of scientific information* among the South African population. Whilst data of this type is available within large market research surveys such as the *All Media and Products Survey* (South African Audience Research Foundation – AMPS) – relating it back to specific *attitudes* to science as well as the measures of scientific *knowledge* – *interest* and *Informedness* remains impossible with AMPS data[77].

INFORMATION SOURCE	Most Frequently	Frequently	Least Frequently
Satellite Pay Television (DsTV, TopTv)	1	2	3
Free-to-Air Television (SABC / e.tv)	1	2	3
Radio	1	2	3
Newspapers	1	2	3
News Websites	1	2	3
Institutional Websites (University / Research Lab)	1	2	3
Government Announcements	1	2	3
Blogs	1	2	3
Social media (Facebook, Twitter)	1	2	3
Other people (Family, Friends, Colleagues)	1	2	3
Books / Magazines	1	2	3

Table 4.8: Information sources about science question from current 2015 Khayabus survey module

The items in the above list represent the 11 most commonly used science information channels accessed in South Africa. While this list contains fewer information formats, the information channel

[76] *Informedness* refers to how informed a respondent feels in relation to particular fields of science
[77] Largely due to the limitation of SAARF-AMPS data that does not investigate science engagement activities

is of most interest within this question as it differentiates the various information sources to best understand scientific information acquisition beyond technological penetration. The differentiation between *pay-television* and *free-to-air* broadcasters as well as the distinction made between *institutional*, *news*, *government*, *blog* websites and social media is of primary importance in the construction of this question. This is a notable advancement on previous studies on the public understanding of science in South Africa, as earlier studies had amalgamated all online media content into a category called '*the internet*' and *television* as an information source had not previously been segmented into *pay tv* and *free-to-air* stations. The selected items provide a high-definition view of South Africans' science media consumption habits as well as the potential for targeted segmentation of the many publicS in South Africa. Similar to Section D, in Section E respondents are asked to indicate how frequently they encounter *information* about science for each of the 11 information channel categories, using a 3-point scale related to *frequency*.

Section F requests information from respondents relating to how frequently they may have encountered or attended science engagement activities, within the preceding 12-month period. While many of these would ordinarily not be considered *science engagement activities* by general members of the public, the questions allow for an assessment of attentiveness to science within the reference period by participating respondents.

SCIENCE ENGAGEMENT ACTIVITIES	YES	NO
Public Library	1	2
Zoo or Aquarium	1	2
Museum (any)	1	2
Science Centre, Technology exhibition	1	2
Science Fair, Festival or similar Public Event	1	2

Table 4.9: Science Engagement activities question from current 2015 Khayabus survey module

4.2.3 Quality Assurance: Questionnaire Testing and Pilot Procedures

Chapter 3 outlines an extensive review of the literature stemming from the study of scientific literacy and the public understanding of science. Reviewing the research instruments employed in those studies, the design and construction of the present research instrument is greatly influenced on those foundations. As such, the quality assurance methods employed in the initial development of specific item-text within the current research instrument borrows from the processes employed by the authors of the source material[78]. Throughout the development of the research instrument as well as its constituent parts and items, considerations of *validity* and *reliability* informed each step of the formulation process. In the review of the literature as well as the development of the six

78 See specifically: Pouris : 1991, 1993; Laugksch, 1996; Blankley & Arnold, 2001; Shukla & Bauer, 2009; Reddy et al, 2010, among others NSF (USA); EuroBarometer (EU); CAST (China); HSRC (South Africa); MOSTI (Malaysia)

elements of PUS and the construction of the research instrument, the inclusion of all the elements that are understood to influence the South African public understanding of science was considered of paramount importance. While limitations such as the length of the questionnaire and the associated cost considerations of running a nationally representative survey were present, all six elements have been included within the 6-part research instrument. All the items adopted or edited from previous surveys have been validated and shown empirically to possess a high-degree of *reliability* and *validity* [24]. Similarly, items developed for this study have been based on the design and structure of items that have appeared in previously mentioned studies[79].

The research instrument underwent an iterative 4-stage quality assurance process. The initial phase was in the development of the questionnaire sections and items, built on the foundations of previously undertaken rigorous research within this domain, adopted the same or structurally equivalent questionnaire items. The questionnaire items in their pre-final format were quality checked by the research supervisor prior to the instrument entering phase 2. Professional colleagues [28] in the domain of STI studies were consulted and requested to further review and assist in refining the items to be included in the research instrument. Feedback from this initial review was collated and incorporated (where appropriate[80]). Phase 3 involved preliminary field trials and later pilot testing the questionnaire, while Phase 4 involves the iterative step of review by the research supervisor and final approval of the research instrument.

Field trials were conducted with individual question-sections and not the entire questionnaire. This was done to obtain feedback on each question-section and section items prior to incorporating all sections in the final research instrument. Each section of the questionnaire underwent five field trials with randomly selected respondents within the City of Cape Town. Feedback from the field trials were recorded and later incorporated into the instrument (where appropriate[26]). Following the initial field trials, Version 0.1 of the research instrument was produced and reviewed by the research supervisor.

The design of the questionnaire includes six (6) sections; Section B, C, D, E and F received a positive response in field trials and were approved for inclusion by the research supervisor. *Section A* (*science knowledge* areas) initially included 25 items which, through a collaborative review process with the research supervisor[81], was reduced to include 15 items. These items were then to be considered

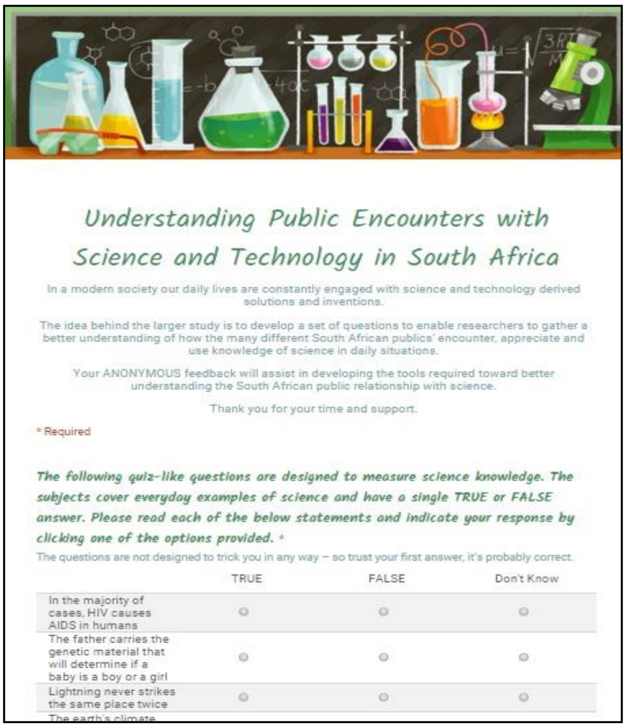
79 While the specific item text may vary, the design, structure, validation and testing methods have been replicated on a smaller scale in the present study

80 Where suggested edits included elements that lengthened or structurally changed the questionnaire these could not be accommodated because of cost considerations.

[81] Mostly due to suitability and quality reasons. As an example the item: "The use of mobile telephones could be hazardous to human health" was removed for quality reasons.

during a pilot, in order to select the most appropriate items for the final research instrument. The pilot study for this research was conducted using both online and face-to-face methods to increase the number of responses toward making the final item selections and refining the research instrument.

The face-to-face pilot was conducted in Cape Town, during June 2015, with the support of colleagues at the HSRC[82]. The face-to-face pilot yielded 100 responses from interviews conducted in respondents' homes, and lasted, on average, 25 minutes. The longest of these pilot interviews lasted 35 minutes and the shortest was 19 minutes. Respondents were from all population groups, genders, age cohorts and a variety of socio-economic/geographical locations in Cape Town[83]. The online pilot was run simultaneously (during June 2015) by developing a web-based form that replicated the research instrument (see image 4.1). The form was launched and its URL link was shared on the author's personal social media platforms[84].


Understanding Public Encounters with Science and Technology in South Africa

In a modern society our daily lives are constantly engaged with science and technology derived solutions and inventions.

The idea behind the larger study is to develop a set of questions to enable researchers to gather a better understanding of how the many different South African publics' encounter, appreciate and use knowledge of science in daily situations.

Your ANONYMOUS feedback will assist in developing the tools required toward better understanding the South African public relationship with science.

Thank you for your time and support.

* Required

The following quiz-like questions are designed to measure science knowledge. The subjects cover everyday examples of science and have a single TRUE or FALSE answer. Please read each of the below statements and indicate your response by clicking one of the options provided. *

The questions are not designed to trick you in any way – so trust your first answer, it's probably correct.

	TRUE	FALSE	Don't Know
In the majority of cases, HIV causes AIDS in humans	○	○	○
The father carries the genetic material that will determine if a baby is a boy or a girl	○	○	○
Lightning never strikes the same place twice	○	○	○
The earth's climate			

Image 4.1: Screenshot of the online pilot web form

As is the nature of social media, the URL links were retweeted and reposted multiple times over a short period and as the survey had an automated close-off at 120 responses, the pilot was completed in two (2) days following the launch. The data was cleaned and all invalid responses[85]

[82] See acknowledgements section for individual names
[83] The selection of the respondents in the pilot was convenience-based or of those within social media networks and thus was not representative.
[84] Social media platforms used included Facebook, Twitter, Whatsap and Linked in
[85] Here I include responses from outside the borders of South Africa, incomplete and spoilt responses – 2 respondents clicked multiple age and population groups.

were removed prior to analysing the results separately – for each online and face-to-face – producing a dataset of 200 pilot responses.

GENDER	
FEMALE	53.0%
MALE	47.0%

POPULATION GROUP	
AFRICAN	12.5%
COLOURED	40.0%
INDIAN	43.5%
WHITE	4.0%

AGE GROUP	
18-30	46.5%
31-50	45.0%
51-60	4.5%
60+	4.0%

Table 4.10: Demographic characteristics of combined pilot sample (N=200)

While it was known that both pilots would not produce representative data, the results nonetheless influenced the final item selection for *Section A* of the research instrument. Following review of the data and the identification of the items offering the greatest discriminatory value within the 15 test items piloted, a 9-item list (Table 4.4) was selected for inclusion in the questionnaire. The research instrument (Version 1.0) was then checked for consistency, and the language edited and tested by senior researchers at the *Centre for Science, Technology and Innovation Indicators* (CeSTII) at the Human Sciences Research Council. The final version of the instrument was then approved by the research supervisor and is presented appendix A. The final instrument composition and number of items is presented in Table 4.11 below.

Question	Number of Items
SECTION A: Knowledge	**9**
SECTION B: Attitude	**4**
SECTION C: Interest	**7**
SECTION D: Informedness	**7**
SECTION E: Information sources	**11**
SECTION F: Engagement Activities	**5**
TOTAL NUMBER OF ITEMS	**43**

Table 4.11: Final research instrument section and item counts

4.2.4 Ethical Clearance Procedure

The proposal for this research project was completed on 22 September 2011 and an application for PhD project acceptance was made to the University of Stellenbosch Senate Committee. In formal communication dated 25 November 2011, the Senate Committee advised that it had accepted the research proposal and that work on the development and implementation could proceed (see appendix A).

In addition to the Senate Committee approval, prior to fieldwork operations, the University of Stellenbosch required that all research involving human subjects undergo ethical review to ensure that the procedures employed in any research associated with the University was within the regulations of the University as well as internationally accepted ethical guidelines and practices. The application process was completed online, with all supporting documentation, and is not dissimilar to any other ethics clearance procedure[86].

Following review, and a single round of feedback from the committee, upon receiving the author's response to questions raised by the Committee, all matters were finalised and final approval for fieldwork to commence was issued by the Committee on 18 August 2015 (see appendix A).

4.2.5 Fieldwork Procedures

As a result of the size and scope of this project, requiring the rollout of a nationally representative survey covering all nine (9) provinces, 11 language and cultural groups; logistical assistance was required toward implementing the fieldwork component of the research project. It must be noted that all conceptualisation, design, planning as well as data analysis and reporting was completed by the author[87], while the implementation of the fieldwork, only, was commissioned to the fieldwork company. Through the generous support of the research supervisor and the *Centre for Research on Evaluation, Science and Technology* (CREST-University of Stellenbosch), the enormous costs of commissioning the fieldwork component of this study were covered[88].

Following the completion of the research instrument; endorsement by the research supervisor and the approval by the University of Stellenbosch Ethics Committee, the clearance to commence fieldwork was communicated to the fieldwork team. Fieldwork operations were then planned and clearance was provided to IPSOS to proceed with data collection. The timelines and major deliverables for this project are detailed below (Table 4.12).

SIGN OFF ON SURVEY	QUESTIONNAIRE FINALISED	FIELDWORK START	FIELDWORK ENDS	DELIVERY OF RESULTS
23 August 2015	6 September 2015	22 September 2015	1 November 2015	22 November 2015

Table 4.12: Fieldwork timeline and data delivery schedule

The research instrument was dispatched to IPSOS, wherein minor formatting changes were made to ensure that the questionnaire module is compatible with the CAPI system. These minor changes did not impact the questionnaire items, but are related to aesthetic and technical fieldwork notes so as to conform to the Khayabus survey format[89]. Following review of the questionnaire updates[90], the questionnaire was considered final for the implementation of the fieldwork phase within the *Khayabus survey* Wave 2 of 2015. The questionnaire was then translated from English into Afrikaans,

[86] Full procedure, application forms and evidence of approval outcome are available in appendix A
[87] With support from the research supervisor
[88] Detailed timelines, costing and funding support information is found in appendix A
[89] Included inserting interviewer notes, pronunciation of selected words and related fieldworker notes – see appendix A
[90] by the author

Zulu, Xhosa, Setswana, Northern Sotho, and Southern Sotho by professional translators and loaded onto the CAPI system.

Fieldwork for the Khayabus survey was scheduled to last five (5) weeks, from 22 September 2015 to 01 November 2015. A compulsory national fieldworker briefing was held at the Cape Town offices of IPSOS and broadcast nationally to other venues via video conference to ensure attendance by all fieldworkers working on the project. During the briefing all fieldworkers were provided with an introduction to the purpose, value and importance of the planned research by the author. Following this the fieldworkers were led through each question-set and response items in the public understanding of science questionnaire module. This was done to ensure that all fieldworkers were familiar with all concepts and pronunciation of items as well as making them aware of the intended use of the data to encourage reliable and accurate fieldwork data recording. Fieldworkers further had an opportunity to raise any questions about the module, its components or questionnaire items, with no significant matters raised by the group. The contact details of both the account manager at IPSOS and the author were made available to all fieldworkers to address any questions received from the field.

The Khayabus survey operates as an omnibus survey and six (6) confidential modules were run simultaneously in field. IPSOS ran its own pilot process in which the entire questionnaire and all modules were tested together in order to ensure that no negative impacts were recorded as a result of all modules being combined in a single questionnaire, and to confirm that the translated versions were suitable for the fieldwork phase. This was completed with a satisfactory result and fieldwork was commenced on 22 September 2015.

Sampling for the Khayabus survey was completed concurrently by IPSOS, using stratified probability sampling techniques and weighting methods[91]. All adults in South Africa (aged 15 years and older[92]) were considered to be part of the sample selection process. A final sample of 4 123 was identified and later weighted to reflect a national population profile totalling to 37 800 000[93]. Sampling followed a 3-stage selection process starting with the selection of the primary sampling units (PSU's) from within the 2011 South African National Census data. Primary sampling units were selected through a process of stratification and only residential dwellings were considered during the initial sampling step. Step 2 involved the sampling of households within the PSU's using GIS tools and aerial photography to identify the housing units to visit in the fieldwork period. Fieldworkers selected the

[91] As this was an omnibus the author was not involved in the sampling, but did received a detailed briefing on the methods employed for reporting purposes

[92] Though this age cut off was set to 18 years and older for the present module on Public Understanding of Science

[93] Total national population above 15 years old (see StatsSA population statistics 2014-2015)

interview home unit location through the inclusion of every third home within the PSU walking plan for interviewers. All fieldworkers were suitably experienced and trained in the methodologies and appropriate sampling processes for different measurement-locations within the survey (metro, villages, and rural settlements). The third stage of the sample selection process involved using a grid-based system to identify the living unit and the individual that will be invited to complete the survey[94].

The fieldwork interview process involves welcoming and advising the respondent as to the purpose of the interview as well as the intended use of the survey data. They are further advised of the approximate duration of the interview followed by the recording of select personal information of the respondent. All respondents were further advised that participation was voluntary and all responses would remain anonymous and confidential. The personal contact information is not associated with a particular CAPI response in the survey, but is retained as a separate record for the quality assurance practice of back-checks[95]. Following the initial demographic questions, fieldworkers then proceeded to facilitate the respondents through the various questions and modules of the Khayabus survey questionnaire. Upon completion of the survey questionnaire requirements, respondents were offered a non-cash token of appreciation for their time and willingness to participate in the study[96].

After completing the interview, the fieldworker completes control questions, such as the time of day and related quality assurance measures following which the data would be synchronised with a remote database and transmitted via a mobile data connection to the IPSOS network. Data is constantly quality checked and where required updated to the fieldwork team leaders for quality enhancement. Once fieldwork closed off, the data was then cleaned and issued to this research project for analysis and reporting.

4.3 DATA OUTPUTS and INDICATORS of the SOUTH AFRICAN PUBLIC UNDERSTANDING OF SCIENCE

4.3.1 INDICATORS of THE SOUTH AFRICAN PUBLIC UNDERSTANDING of SCIENCE

A key output from this research is the development and presentation of a new set of indicators to further understand the various elements contributing to the overall South African public understanding of science (SAPUS).

[94] Where contact with the identified person was unsuccessful after 3 attempts, a substitution process could be followed.
[95] 20% of responses are confirmed through telephonic back-checks to the field, but not shared with the client (the author)
[96] The specific non-cash token was a nylon sling bag – approximate bulk order value $0.60 (USA) per unit

Chapter five presents the results delineated in response to each of the primary research questions discussed in Chapter One:

1) *What is the Current South African Public understanding of Science (SAPUS)?*

   c. *What is the level of Scientific Knowledge?*

   d. *What attitudes are held by South Africans regarding Science?*

   e. *How interested and informed are South Africans about Science?*

   f. *What are the main information Sources regarding Science?*

   g. *Which are the most frequented Science Engagement activities in South Africa?*

Each of the sub questions will in turn then be cross-analysed with various demographic categories in an effort to understand the key drivers within each PUS element within the contemporary South African publicS.

As such, Chapter Six responds to the secondary research question presented below:

2) ***What predictor variables best explain SAPUS scores?***

   i. *How do SAPUS scores vary according to various demographic segments?*

   ii. *Which demographic variables show predictive value in explaining SAPUS scores?*

In Chapter Six results from the Khayabus survey are used to present the set of six (6) indicators developed from within the data outputs from each question set. These results are further disaggregated by various demographic classifications demonstrating its value and application to this research area within the South African landscape.

The *science knowledge index* produced an indicator consisting of three (3) points, classifying respondents' as demonstrating a level of knowledge ranging from *low scientific knowledge, moderate scientific knowledge* or *high scientific knowledge*. This index adopts the *sum knowledge score* achieved across all nine (9) items by each respondent and through an empirically driven classification system (to be discussed in chapter six), to categorise respondents within one of the index levels.

The *index of attitudes to science* adopts the respondents' scores obtained through a recoding process to classify respondents within one of three (3) attitudinal classifications (to be discussed in Chapter Six). This index has been designed to classify respondents as possessing either a *negative attitude to science*, *ambivalent attitude to science* or a *positive attitude to science*. This indicator similarly adopts the *sum attitudinal score* achieved by individual respondents across all four (4) attitudinal items, and classifies respondents accordingly, based on score realised. The result for each respondent is then aggregated to obtain an overall national result within the *index of attitudes to science*.

The individual result for each respondent on the *interest* and *informedness* question set will be recoded and a score obtained for each valid response[97]. These scores will be used within the development of an *Index of Interest in Science* as well as *Index of Informedness about Science*. These two indices share much in their development, validation and outputs and are addressed collectively despite their independent outputs and contribution to this work. Both indices will output three (3) levels within each respective indicator. The *Index of Interest in Science* will classify respondents based on their individual *sum interest* score as either possessing a *low interest in science*; a *moderate interest in science* or as having a *high interest in science*. Similarly, the *Index of Informedness about Science* will classify respondents based on their individual *sum informedness* score as either possessing a *low informedness in science*; a *moderate informedness in science* or a *high informedness in science*. Each index, its development and validation will be presented independently in Chapter Six.

The responses within the science information source items in the questionnaire will be used in the development of a (*scientific*) *information immersion* Index. This index will present the results of respondent selection within the questionnaire categories[98] to produce a *sum information immersion* score for each respondent. This *sum information immersion* score is constituted by the respondent selections of both count and frequency of exposure to varying science information sources. This score will then be used within a classification system (to be discussed in Chapter Six), to classify respondents within one of the index levels. The *information immersion* Index will classify respondents as either possessing a *low* (*scientific*) *information immersion*; a *moderate* (*scientific*) *information immersion* or as having a *high* (*scientific*) *information immersion*. As with the other indices, the results produced herein will be presented for the national sample as well as for selected demographic cohorts.

The *index of science engagement* adopts an average *sum engagement score* comprised of the respondent selections across the five questionnaire items[99]. The *sum engagement score* represents a count of engagement activities attended by individual respondents within the preceding 12-month period. The *sum engagement score* is then used to classify respondents as either demonstrating a *low level of science engagement*; a *moderate level of science engagement* or a *high level of science*

[97] This will exclude *no interest* selections
[98] On a recoded response variable – highest code (3) = most frequent, lowest code (1) = least frequent. D/K = 0
[99] This index presents *attendance* selections only and does not take *NO* selections into account.

engagement. The specific development and validation of this index will be addressed within the later chapters along with the results for overall and various sub-samples.

Chapter 6 will further include the result of the multinomial logistic regression analysis that will highlight the influence of the various demographic variables on respondents' performance within each index. The contribution of this analysis will result in the development of models to explain the influence of selected demographic variables as predictors of performance within each index result. The relative goodness of fit as well as related assessment measures of the models produced will be presented and discussed within the concluding sections of chapter six. The results of this research are now presented in the following chapters.

Chapter Five

Descriptive Survey Results:

Scientific Knowledge Assessment

We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology.

Carl Sagan (1990)

Introduction

The next six chapters present the results and key findings on the six areas included in the survey. These six areas address the following research questions:

1) What is the level of scientific knowledge among the South African public?
2) What attitudes are held by South Africans regarding science?
3) How interested are South Africans about science?
4) How informed are South Africans about science?
5) What are the main science information sources for South Africans?
6) Which are the most frequented science engagement activities among South Africans?

Further to these headline results, data on various demographic classifications was also collected within the *Khayabus Survey* which will provide further insight into the results by allowing the data to be viewed through various socially constructed lenses. These demographic classifications do not always demonstrate an independent relationship between variables, but display multiple levels of interactions between demographic variables. Further to this, these demographic variables continue to display the many legacy impacts of apartheid and this impact does manifest within the data analysis[100]. The most salient demographic classifications were selected, including race[101]*, age, gender, language, educational attainment*, ho*usehold income* as well as *geographic location*.

The following six chapters present the main results and findings per area. In order to ensure the reliability and validity of these results, a set of rigorous reliability analyses were conducted for each set of items. The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

[100] This is particularly visible for *Race, Gender, Employment status, Income* and *Education*

[101] While the term "*population group*" and "*race*" are at times used interchangeably in South Africa, within this document, the term "race" is adopted as it is consistent with the official terminology used by Statistics South Africa (StatsSA)

WHAT IS THE LEVEL OF SCIENTIFIC KNOWLEDGE AMONG THE SOUTH AFRICAN PUBLIC?

The participants in our national survey on average scored 40.3% of the items on scientific knowledge correctly. However, this score hides the considerable variance across individual items (table 5.1).

		Scientifically Correct	Scientifically Incorrect	D/K
1	In the majority of cases, HIV causes AIDS in humans	**67.4%**	18.7%	13.9%
2	Lightning never strikes the same place twice	**32.7%**	45.2%	22.1%
3	South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	**39.5%**	27.3%	33.2%
4	The continents which we live on are continually moving due to forces deep within the Earth	**46.2%**	24.9%	28.9%
5	The price of petrol in South Africa is NOT influenced by the price of crude oil	**35.5%**	40.8%	23.7%
6	Schizophrenia is the same as Multiple Personality disorder	**24.4%**	42.0%	33.6%
7	The father carries the genetic material that will determine if a baby is a boy or a girl	**46.6%**	33.2%	20.3%
8	The earth's climate has NOT changed over millions of years	**41.7%**	33.8%	24.5%
9	The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	**28.4%**	34.3%	37.3%

Table 5.1: Results of *Science Knowledge* question bank in Khayabus wave 2, 2015

As discussed in Appendix 1, the items measuring "scientific knowledge" were clearly experienced very differently by our respondents: *item 1* (67.4%), *item 7* (46.6) and *item 4* (46.2%) recording the highest number of *scientifically correct* responses, while item 9 (24.8%); item 6 (24.4%) and item 2 (32.7%) recorded the highest number of scientifically incorrect responses. Only item 9 received more *don't know* response selections (37.3%), compared to the other items.

The question "*In the majority of cases, HIV causes AIDS in humans*" recorded the highest proportion of *scientifically correct* responses (67.4%). This is likely as a result of the numerous health, wellness and public information campaigns within South Africa related to the area of HIV risk behaviour. However, it is still important to emphasize that nearly a third (32.6%) of respondents did not provide a correct response to this item. The second item, related to the area of *Biological Sciences- Genetics* recorded the next highest number of *scientifically correct* responses (46.6%); followed by *Physical Sciences – Geology* (46.2%), *Earth Science - Climate Change* (41.7%) and *Social Science – History* (39.5%).

Items recording a higher numbers of *scientifically incorrect* responses include subject areas of *Social Science Economics* (40.8%), *Physical Science – Electricity* (45.2%) and *Social Science Psychology* (42.0%), indicating a generally lower degree of scientific knowledge within in these areas (chart 5.6).

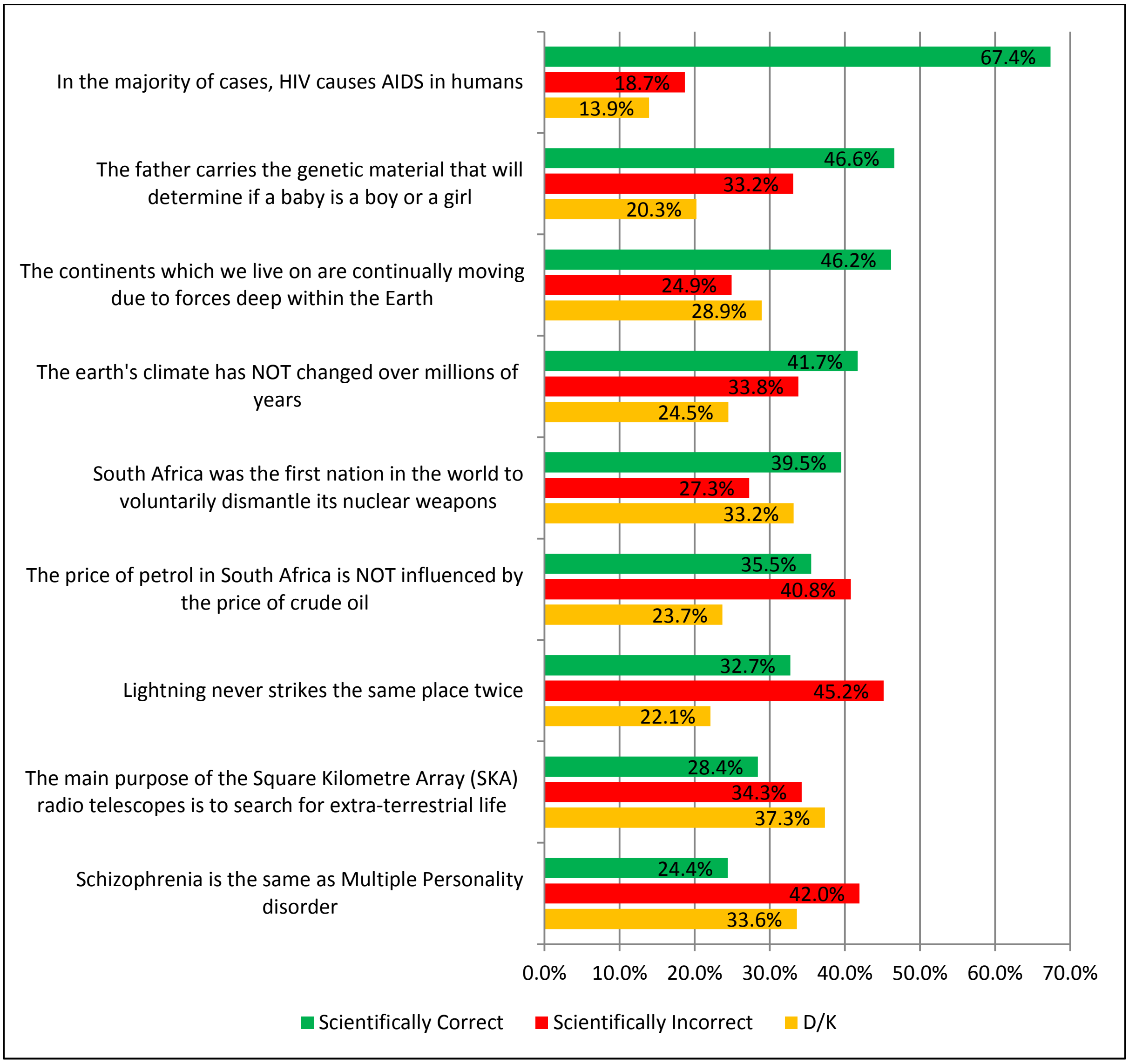


Chart 5.1: Response per item in the *Science Knowledge* assessment (Khayabus wave 2, 2015)

The item dealing with the area of *Astronomy:* "*The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life*", recorded the highest proportion of *don't know* responses (37.3%). This may indicate that despite large investments in public engagement and marketing activities surrounding the SKA project, public knowledge about its intended purpose and planned projects remain low. Overall these results indicate a generally low level of knowledge about science among the general South African population.

Levels of scientific knowledge with respect to major demographic variables are briefly presented below. Table 5.2 presents the summary data and is followed by a detailed appraisal of each demographic variable.

	SCIENTIFICALLY CORRECT	SCIENTIFICALLY INCORRECT	D/K	N
NATIONAL	**40.3%**	**33.3%**	**26.4%**	**3 486**
RACE	**N = 3 486**			
BLACK	**38.3%**	32.2%	29.5%	**2 523**
WHITE	**49.9%**	37.7%	12.4%	**408**
INDIAN / ASIAN	**44.1%**	40.9%	15.1%	**121**
COLOURED	**41.3%**	34.0%	24.7%	**434**
GENDER	**N = 3 486**			
FEMALE	**39.3%**	32.4%	28.3%	**1 747**
MALE	**41.3%**	34.2%	24.5%	**1 739**
GEOGRAPHIC LOCATION	**N = 3486**			
URBAN	**41.7%**	34.1%	24.2%	**2 297**
RURAL	**37.5%**	31.8%	30.7%	**1 189**
EDUCATION	**N = 3486**			
PRE-MATRIC	**36.1%**	29.5%	34.4%	**1 369**
MATRIC COMPLETED	**41.7%**	35.7%	22.6%	**1 578**
POST-MATRIC	**46.8%**	36.3%	16.9%	**539**
AGE	**N = 3 472**			
<20 YEARS	**38.1%**	30.0%	31.9%	**170**
20-29 YEARS	**39.3%**	33.6%	27.1%	**1 101**
30-39 YEARS	**40.8%**	34.0%	25.2%	**956**
40-49 YEARS	**41.4%**	34.5%	24.1%	**598**
50-59 YEARS	**41.5%**	32.8%	25.7%	**372**
60+ YEARS	**39.2%**	30.1%	30.7%	**275**

Table 5.2: Results of *Science Knowledge* by demographic classifications in Khayabus wave 2, 2015

There is a significant difference in the level of scientific knowledge of respondents from different race classifications (X^2=161.841, $p < 0.001$). White respondents provided more scientifically correct responses (49.9%) followed by Indian / Asian (44.1%) and coloured (41.3%) respondents. Black respondents presented the lowest overall proportions correct response (38.3%), a result not entirely unexpected considering the multiple sociodemographic challenges across South African race groups.

Gender demonstrated a statistically significant relationship to the overall population response on the 9-item science knowledge assessment (X^2=18.783, $p < 0.05$). The average proportion of *females* providing a correct response was 39.3% compared to 41.3% among males (n = 3 486). This is in agreement with international and domestic evidence of the role of gender with respect to the overall level of scientific knowledge (European Commission, 2013a). However, it is worth emphasizing that the differences between male and female responses remain small.

At the aggregate level, geographic location was assessed by each of the 9 South African provincial demarcations as well as by the rural / urban classification. Analysis of the overall response to scientific knowledge items by province demonstrated a statistically significant difference in the recorded scores (X^2=327.519, p < 0.001). The recorded outcome on scientific knowledge measures for *urban* respondents was significantly higher (41.7%) than for rural (37.5%) respondents (X^2=45.888, p < 0.001).

Educational attainment is known to be associated with performance on *scientific knowledge* measures (Blankley and Arnold, 2001; Reddy *et al,* 2009). As per the earlier noted expectation, *educational attainment* was found to be a highly significant factor within the recorded outcomes on the 9 questionnaire items (X^2=152.279, p < 0.001). Respondents with *pre-matric educational attainment* demonstrated lower scores on the scientific knowledge assessment (36.1%) compared to those with post-matric educational qualifications (46.8%). Among respondents able to provide correct responses to 6 or more (of the 9) questions, 12.5% had a *pre-matric* education, compared to 23.9% of respondents with a *post-matric* education.

A*ge* of respondents was not found to show a statistically significant association with measures of *scientific knowledge* (X^2=61.175, p > 0.05). While there was a pattern of higher recorded response for those aged between 20 and 59 years old, this was likely related more to employment and educational attainment and was not found to carry a statistically significant association to the age of respondents.

EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH KNOWLEDGE OF SCIENCE

The aim of the following discussion is to disaggregate the data by looking at the bivariate relationships between a number of key demographics and the responses to the scientific knowledge items. In Chapter 11 we present the results of a rigorous multinomial logistic regression for each of the outcome variables. In the remainder of this chapter, however, we will focus on how gender; race; household income; educational attainment; geographic location (rural-urban); employment and age are related to respondent's knowledge of science. CHAID is a statistical technique that allows one to explore these relationships interactively. It identifies which, in a set of demographic variables are most likely to correlate with the "dependent" variable. By itself it is not adequate to generate strong conclusions about these relationships, but it is a very useful technique to identify such key variable toward further more rigorous analysis (hence the regression analysis in Chapter 11).

In Figure 5.1 we present (in graphic form) the results of the CHAID analysis for the knowledge of science items within this data set. The analysis was completed adopting the composite score across all seven knowledge of science items. The following categorical variables were entered into the analysis: *gender; race; household income; educational attainment; geographic location (rural-urban); employment* and *age.*

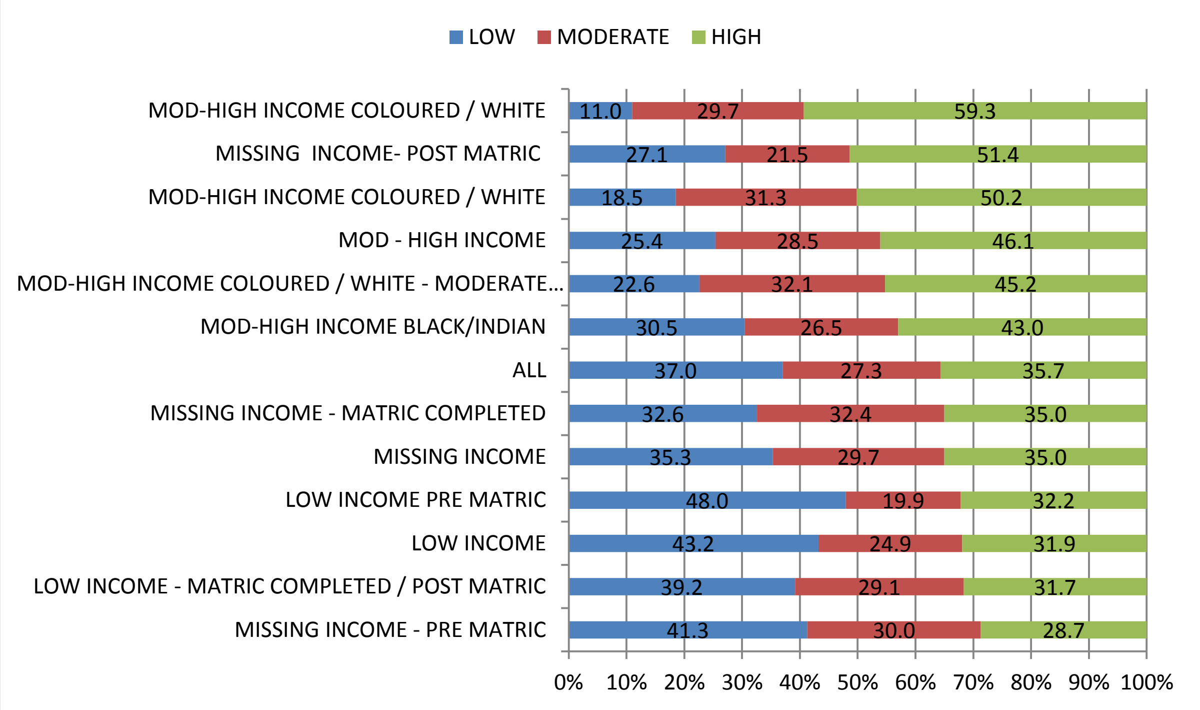


Figure 5.1: Output of CHAID analysis: Knowledge of Science

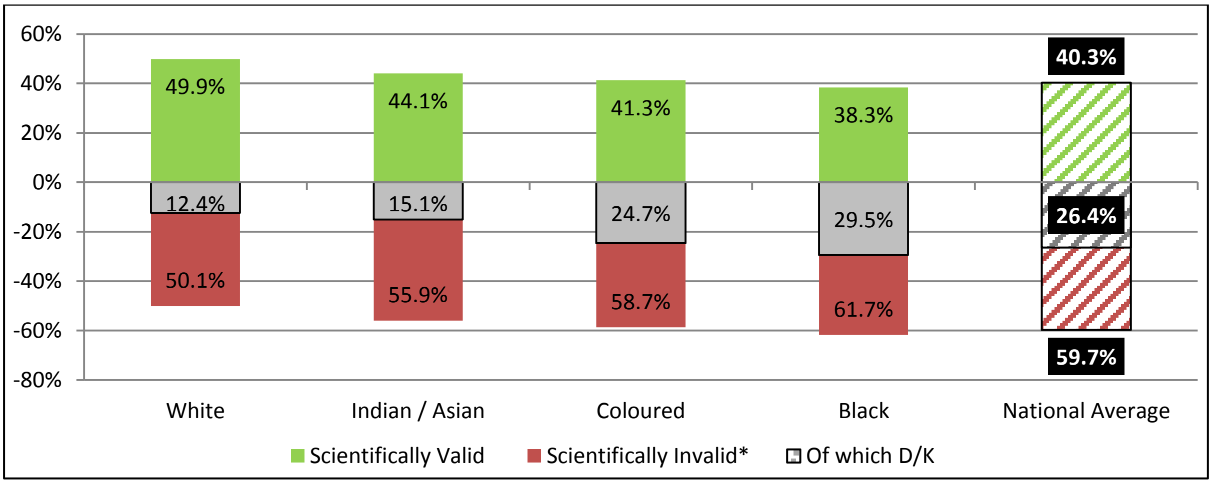
The result of the CHAID analysis shows that three demographic variables are the best predictors of respondent level of scientific knowledge. These predictor variables are *household income, race* and *educational attainment* level. To illustrate: white and coloured respondents who were categorized as falling in the moderate and high household income brackets, recorded the highest percentage of correct responses (59.3%) on the scientific knowledge index. At the other extreme, respondents with pre-matric educational attainment and lower levels of household income recorded much lower levels of scientific knowledge.

Each of these predictors will be addressed in some detail across the next sub-section of this chapter. The three predictors, along with additional variables of conceptual and statistical significance will be included in the *multinomial logistic regression* modelling toward the output of a predictive model of scientific knowledge measures in South Africa.

SCIENCE KNOWLEDGE BY RACE

The classifications adopted within this research reflect the racial categories used in general administrative data streams within contemporary South Africa. The 4 primary race classifications which have been transposed into the nomenclature of democratic South Africa are not without contestation. However, in the interest of highlighting some of these legacy impact challenges of the apartheid system, this research employs these categories, toward emphasizing the many social inequalities still prominent in contemporary South Africa.

The previous section highlighted the statically significant relationship between assessed *scientific knowledge* and *race classifications* within the general South African population (X^2=161.841, p < 0.001). On average, white, Indian / Asian and coloured respondents reported more correct responses compared to black participants. Despite this, the Indian / Asian cohort of respondents provided a greater proportion of incorrect responses (40.9%) compared to white (37.7%), coloured (34.0%) and black (32.2%) respondents. A similar pattern is reflected in the selection of the *don't know* response category, where black (29.5%) and coloured (24.7%) respondents provided more frequent *don't know* responses compared to Indian / Asian (15.1%) and white (12.4%) respondents. This indicates that overall, black and coloured respondents are more likely to acknowledge a *knowledge gap*, than hazard an *incorrect* response, compared to white and Indian / Asian respondents. However, black respondents provided the lowest levels of scientifically correct response across the question set, 2.0% below the overall national average (see chart 5.2).



*** Scientifically incorrect includes *Incorrect* and *D/K* responses**

Chart 5.2: Average response by race: *Scientific Knowledge* assessment (Khayabus Wave 2, 2015)

The role of race on measures of *scientific knowledge* can further be explored by science subject area, per questionnaire item. Table 5.3 illustrates the comparison to the national average response, by race, for each of the questionnaire items. White respondents generally responded above the national average for all questions, except for the item related to *Social Science - Psychology* (-2.6%). White respondents demonstrated a significantly better understanding of *climate change*, scoring 20.3% above the national average for this item (X^2= *151.650; p* < 0.001). Black respondents generally scored below the national average across all items, except for *Social Science – History* (+0.1%); *Social Science – Psychology* (+0.3%) and *Biological Science – Genetics* (+0.4%). Indian / Asian respondents reported scores higher than the national average for 8 of the 9 items, however did produce significantly higher result for the item related to *Social Science – Psychology* (+12.0%; X^2= *202.654; p* < 0.001). Coloured respondents responded higher than the national average for 5 of the 9 items, however did display a significantly lower result within the item: *Social Science – History* (-6.8%; X^2= *47.374; p* < 0.001).

	SCIENTIFICALLY CORRECT RESPONSES				
	White	Black	Indian / Asian	Coloured	**National Average 2015**
BIOLOGICAL SCIENCE - MEDICAL	8.1%	-1.5%	0.4%	1.3%	**67.4%**
PHYSICAL SCIENCE - ELECTRICITY	11.9%	-1.7%	0.3%	-1.6%	**32.7%**
SOCIAL SCIENCE - HISTORY	6.8%	0.1%	-1.5%	-6.8%	**39.5%**
PHYSICAL SCIENCE - GEOLOGY	17.8%	-3.6%	4.3%	2.9%	**46.2%**
SOCIAL SCIENCE - ECONOMICS	17.2%	-4.0%	9.9%	4.1%	**35.5%**
SOCIAL SCIENCE - PSYCHOLOGY	-2.6%	0.3%	12.0%	-2.5%	**24.4%**
BIOLOGICAL SCIENCE - GENETICS	0.7%	0.4%	3.0%	-3.7%	**46.6%**
EARTH SCIENCE - CLIMATE CHANGE	20.3%	-4.6%	2.1%	6.9%	**41.7%**
ASTRONOMY - SKA	6.6%	-2.8%	3.8%	9.2%	**28.4%**

Table 5.3: Science subject area by race classifications (to national average) in Khayabus Wave 2, 2015

Chart 5.3 reveals that *white* and *Indian* respondents respond above the level of the national average for most questions, while *black* and *coloured* respondents generally respond lower than the national average.

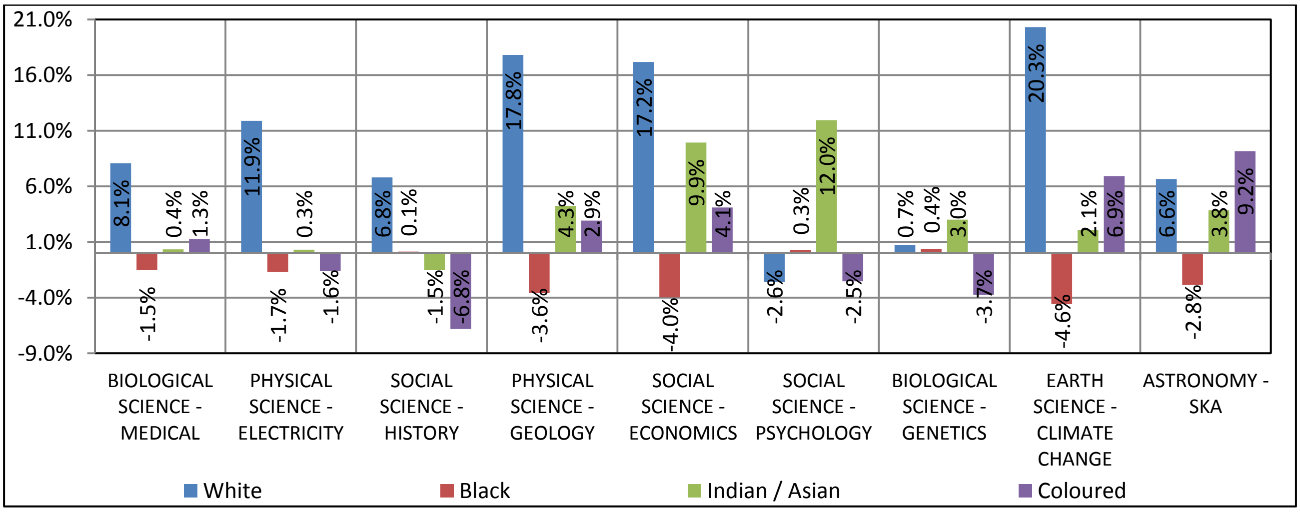


Chart 5.3: Response to *Science Knowledge* assessment by race groups: comparison to national average

Within the cross tabulation for *race* and scores on the *scientific knowledge assessment*, a further layer variable was included to create 3-way contingency tables. This analysis was completed to assess the role of a further variable in this analysis to better understand the results within this study. The below section briefly discusses the results of this analysis for the additional layers of: *gender; rural / urban location; educational attainment; age; employment status* and *household income.*

Within race there are variations between the scores of male and female respondents, yet there was no significant association as a result of gender on knowledge assessment scores (White: X^2=0.395, $p > 0.05$; Black: X^2=1.845, $p > 0.05$; Indian: X^2=0.042, $p > 0.05$; Coloured: X^2=0.527, $p > 0.05$). When comparing the variations that exist between males and females of different race groups, for both genders there was a significant association between the variables *gender* and *race* (Male: X^2=24.371, $p < 0.001$; Female: X^2=39.087, $p < 0.001$). White males and white females tend to score significantly higher than members of their respective gender grouping within other race groups. This does not discount the important role of gender dynamics within the South African context, but implies that within the envelope of socioeconomic dynamics, *race* may exert a statistically significant greater effect than gender; within the contemporary South African context.

Rural and urban respondents do show a statistically significant difference in their science knowledge assessment scores. Within race categories there was no statistically significant association between rural / urban populations and scientific knowledge for white (X^2=24.371, $p > 0.05$), coloured (X^2=0.001, $p > 0.05$) and Indian / Asian (X^2=1.384, $p > 0.05$) respondents. However, among black respondents there was a statistically significant association recorded for these variables, likely as a result of the larger black rural population in South Africa (X^2=8.227, $p < 0.01$). Irrespective of rural / urban geographic location, white respondents provided more correct responses, compared to other race categories, highlighting a significant association between *race* and *knowledge assessment scores*, (Urban: X^2=44.069, $p < 0.001$; Rural: X^2=12.019, $p < 0.05$).

Analysis of the scores for the *science knowledge assessment* by *race* and *educational attainment* level reveals varying degrees of association between these variables. Despite the overall contribution of increased educational attainment on response to the knowledge assessment items, two distinct outcomes emerged. White and Indian respondents did not display a statistically significant association between these variables (White: X^2= 4.00, $p > 0.05$; Indian: X^2= 3.107, $p > 0.05$). However, for black and coloured respondents there was a statistically significant association between scores on the scientific knowledge assessment and educational attainment categories (Black: X^2= 45.031, $p < 0.001$; Coloured: X^2= 11.839, $p < 0.05$). The role of educational attainment across race classifications reveals similarly interesting findings.

Among individuals with *pre-matric* and *post-matric* education, irrespective of race, there is very strong evidence that the variables *race* and *score on science knowledge* assessment are associated within the population (Pre-Matric: X^2= 14.317, p < 0.05; Post-Matric: X^2= 25.575, p < 0.001). However, irrespective of race, individuals with a completed matric qualification this association is not as well supported by the evidence (Matric Completed: X^2= 7.435, p > 0.05).

Within all race classifications, age did not demonstrate a significant association to *race* and scores on the *science knowledge assessment*. However, across race groups, age classification showed some association to *race* and scientific knowledge scores, particularly for the older members of the sample. Age groups *<20 years*; *20-29 years* and *50-59 years* did not show a significant association with these variables. However, age groups *30-39 years* (X^2= 20.721, p < 0.001); *40-49 years* (X^2= 14.472, p < 0.05) and *60+ years* (X^2= 22.957, p < 0.001) were found to be significantly associated with *race* and knowledge assessment scores. This is likely due to the race-based differential influence of apartheid on older South Africans compared to those within the *born-free* generation[102]. This is evident when examining the higher scores achieved by white South Africans across all age groups, compared to those achieved by similarly aged black South Africans.

Race classifications exhibited minimal variation in achieved *knowledge assessment* scores by *employment* categories for white and black respondents. While there was some variation within the Indian group between scores achieved by those *Employed* and those achieved by *Unemployed* or *Other (Not Working)* respondents, none of these were found to be statistically significant. Among coloured respondents however, the association between *employment* status and scores on the knowledge assessment was found to be statistically significant (X^2= 13.940, p < 0.01). The role of *employment* status, across all *race* groups did not highlight a significant association between the scores achieved for *unemployed* individuals within black, white, coloured or Indian respondents (Unemployed: X^2= 7.454, p > 0.05). Conversely, for individuals within the *employed* or *Other (Not Working)* category, a highly significant association was found between *race* classification and scores on the *knowledge assessment* items (Employed: X^2= 37.280, p < 0.001; Other (Not Working): X^2= 19.266, p < 0.001).

Household Income levels have an overall highly significant association with *race* classifications in South Africa (X^2= 630.170, p < 0.001). Within the black, white and coloured sub-samples, higher income was similarly associated with higher levels of scientific knowledge (Black: X^2= 26.386, p < 0.001; White: X^2= 15.364, p < 0.001; Coloured: X^2= 24.206, p < 0.001). This association was not found for respondents within the Indian / Asian classification, where science knowledge scores increased

[102] South Africans born post-1994

within the *low* to *moderate* income group, however decreased between the *moderate* to *high* income classification (Indian: X^2= 2.047, p > 0.05). Though there is a statistically significant association between *household income* and response on scientific knowledge measures, these do not manifest across race groups as they do within race groups. Within *low* and *moderate household income* groupings, despite the variations in knowledge assessment scores for *race* classifications, no significant association was found between the three variables. However for the *high income* group, a significant association was found between knowledge assessment scores, *race* and *household income* level (High Income: X^2= 12.356, p < 0.05). This is likely as a result of the moderating effect and interactions between the *race*, *education level*, *household income* and *employment status* variables still influencing contemporary South African socioeconomic realities.

<u>SCIENCE KNOWLEDGE BY EDUCATIONAL ATTAINMENT</u>

Level of *educational attainment* was found to be statistically associated with scientific knowledge assessment scores (*Education*: X^2= 81.875, p < 0.001).

Response analysis indicates clear patterns within the *educational attainment* variable discussed previously. The highest count of respondents not able to provide a single scientifically correct response was within the *pre-matric* qualification category (12.6%), followed by respondents with a *matric-completed* (6.5%) and then those with a *post matric* qualification (4.5%). Among respondents able to provide between 4 and 9 scientifically correct responses, 48.9% report a *pre-matric* education, compared to 61.2% of those with a *completed matric* and 69.4% of respondents reporting a *post-matric* qualification (see chart 5.11a)

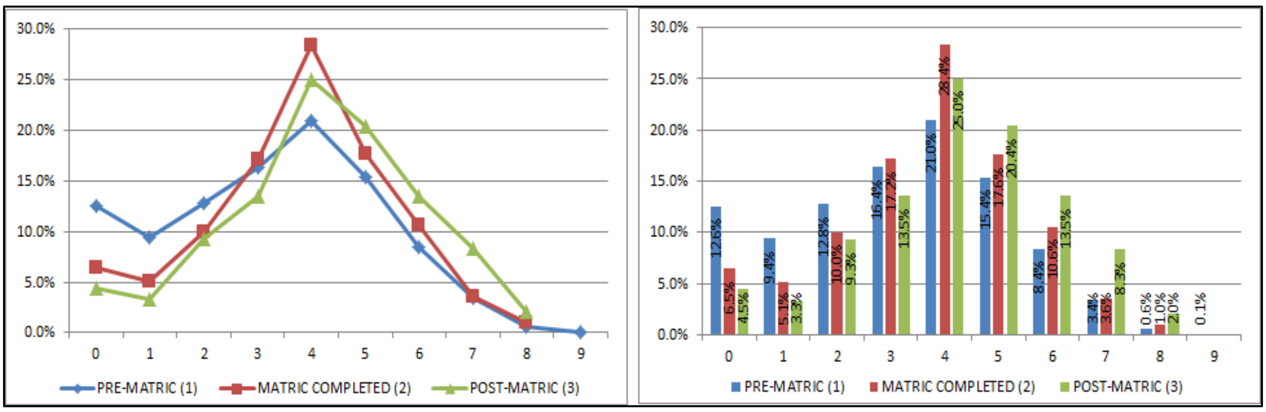


Chart 5.11: Response to *Science Knowledge* assessment by educational attainment groups

Respondents with a *post-matric* qualification were more likely to provide a higher number of scientifically correct responses (see chart 5.11b), compared to those with *pre-matric* education, among which 72.1% were able to provide only 4 scientifically correct responses.

	PRE-MATRIC	MATRIC COMPLETED	POST-MATRIC	NATIONAL AVERAGE
Average SCIENTIFICALLY CORRECT response	36.1%	41.7%	46.8%	**40.3%**
Average SCIENTIFICALLY INCORRECT response	29.5%	35.7%	36.3%	**33.3%**
Average DON'T KNOW response	34.4%	22.6%	16.9%	**26.4%**
	100%	**100%**	**100%**	**100%**

Table 5.7: Response to science knowledge items, by educational attainment (with national average)

Results reflected in table 5.7 confirm that respondents with higher educational achievement are able to provide a greater proportion of correct response compared to those with lower educational achievement. Respondents with a *post-matric* qualification perform 6.5% above the national average compared to those with *pre-matric* educational achievement (4.2% below the national average). Chart 5.12 demonstrates this relationship, wherein those with higher educational attainment are able to provide more correct responses, while at the same time selecting the *Don't Know* response option least frequently.

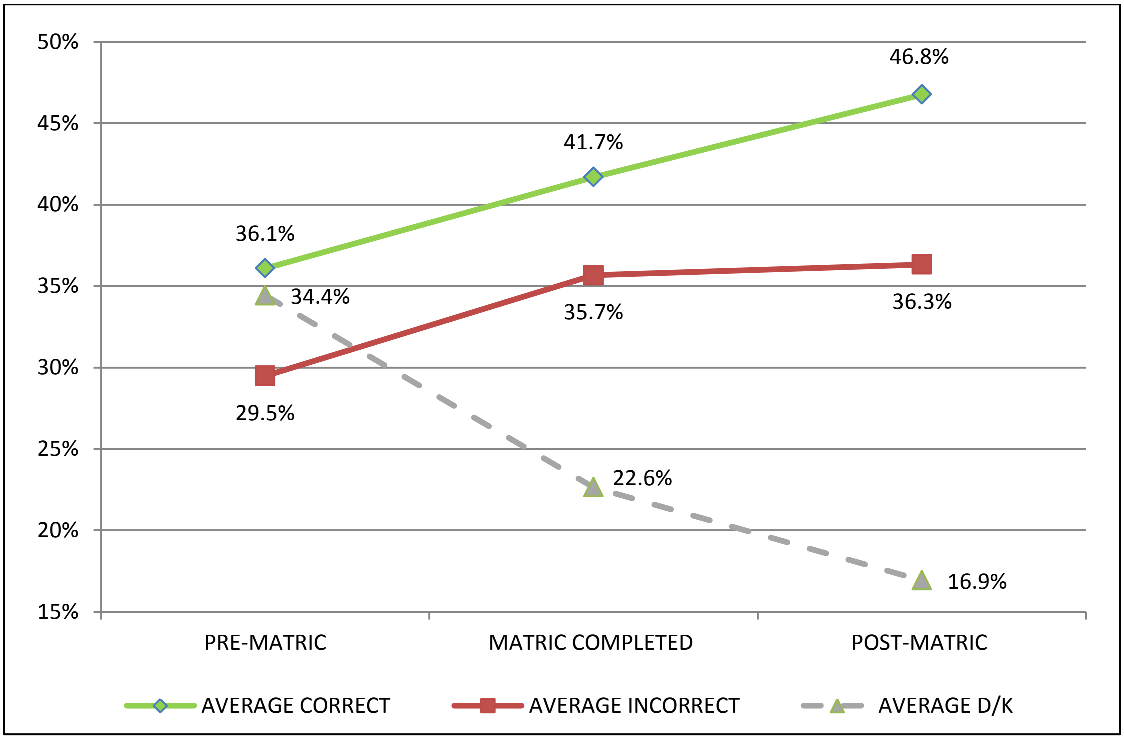


Chart 5.12: Response to *Science Knowledge* assessment by educational attainment groups

Respondents with a *pre-matric* education tend to provide fewer *in*correct responses, but simultaneously present the highest proportion of *don't know* response selections (34.4%). Respondents with a completed matric, while achieving higher proportions of correct responses, also present greater levels of incorrect response. Within both the *matric completed* and *post-matric* categories the use of the *don't know* option is significantly lower than for the pre-matric group indicating a greater confidence in their scientific knowledge, even if in some cases the response provided may be incorrect.

The results of the knowledge assessment by subject area are explored below using the 3 categories of educational attainment as well as the overall national average (table 5.8).

	PRE-MATRIC	MATRIC COMPLETED	POST-MATRIC	**NATIONAL AVERAGE**
BIOLOGICAL SCIENCE - MEDICAL	62.5%	68.6%	76.4%	**67.4%**
PHYSICAL SCIENCE - ELECTRICITY	30.4%	32.7%	38.8%	**32.7%**
SOCIAL SCIENCE - HISTORY	34.5%	41.4%	46.9%	**39.5%**
PHYSICAL SCIENCE - GEOLOGY	37.9%	48.8%	59.4%	**46.2%**
SOCIAL SCIENCE - ECONOMICS	30.1%	38.2%	41.4%	**35.5%**
SOCIAL SCIENCE - PSYCHOLOGY	22.6%	25.9%	24.7%	**24.4%**
BIOLOGICAL SCIENCE - MEDICAL	43.7%	47.3%	51.8%	**46.6%**
EARTH SCIENCE - CLIMATE CHANGE	37.4%	42.5%	50.3%	**41.7%**
ASTRONOMY - SKA	25.7%	29.8%	31.2%	**28.4%**

Table 5.8: Science subject area by educational attainment classifications (to national average) in Khayabus Wave 2, 2015

Response within the *pre-matric* sub-sample was generally below the level of the national average response, while those with a *completed matric* or *post-matric* responded at a level above that of the national average. Among the *pre-matric* group, notable results (compared to the national average) include *Physical Science – Geology* (-8.2%); *Social Science – Economics* (-5.4%) and *Social Science – History* (-5.1%). Among those with a *post-matric* qualification, notable mentions are: *Physical Science – Geology* (+13.2%); *Biological Science – Medical* (+9.0%) and *Earth Science - Climate Change* (+8.6%). The role of a *post-matric* education is highly evident when comparing results from the latter group to those from the *pre-matric* category. Within the items mentioned previously, the variance in scores achieved between the *post-matric* and *pre-matric* groups are as follows: *Physical Science – Geology* (+21.5%); *Biological Science – Medical* (+13.9%) and *Earth Science - Climate Change* (+12.9%). The above results have all been found to be statistically significant with respect to the association between *scientific knowledge assessment* scores and *educational attainment* (for all items $p < 0.001$).

Analyses on *educational attainment* and scores within *science knowledge assessments* have similarly been extended to include a 3rd variable as in preceding sections[103]. These layers will include *age*; *employment status* as well as *household income level* as additional variables to the analysis.

[103] Third layered variable analyses have already been presented in earlier sections for *Location*, *Gender* and *Race* and will not be presented within this section.

E*ducational attainment* is significantly associated with scores on the *knowledge assessment* (*Education*: X^2= 81.875, p < 0.001). This analysis was expanded to include the *age* variable and the results are discussed below. Within the *pre-matric* and *matric completed* groups, no evidence of a significant association was found between the *age* of respondent, *educational attainment* and the *science knowledge assessment* variables (*Pre-Matric*: X^2= 6.919, p > 0.05; *Matric Completed*: X^2= 1.189, p > 0.05). However among those with *post-matric* qualifications (*Post-Matric*: X^2= 20.598, p < 0.01) a statistically significant association was identified. The reported level of *educational attainment* was found to be significantly associated with all age classification groups, except the <20 years group (X^2= 1.916, p > 0.05). This is likely as a result of the fact that 94.7% of participants younger than 20 years old report having *pre-matric* or a *completed matric* qualification and only a very small minority report having any post-matric education. Within every other age category older than 20 years old, a statistically significant association was demonstrated for the variables: *age, educational attainment* and scores on the *knowledge assessment* questions (*20-29 years*: X^2= 20.745, p < 0.001; *30-39 years*: X^2= 18.061, p < 0.001; *40-49 years*: X^2= 7.096, p < 0.05; *50-59 years*: X^2= 25.736, p < 0.001; *60+ years*: X^2= 27.034, p < 0.001).

Analysis investigating the relationship between scores on the knowledge assessment, educational attainment and employment status may indicate a hierarchical association with respect to the influence of these variables. Within each of the three educational attainment categories no statistically significant association was reported between *employment status* and *knowledge assessment* scores (*Pre-Matric*: X^2= 0.679, p > 0.05; *Matric Completed*: X^2= 1.701, p > 0.05; *Post Matric*: X^2= 0.199, p > 0.05). This may indicate a greater influence as a result of increased educational attainment level when compared to respondent employment status. Conversely, within employment status categories the influence of educational attainment was found to be highly significant within all 3 employment categories (*Employed*: X^2= 30.735, p < 0.001; *Unemployed*: X^2= 17.442, p < 0.001; *Other (Not Working)*: X^2= 19.597, p < 0.001). This finding confirms the earlier suggestion that educational attainment classification may have a greater overall role on response to science knowledge assessments, compared to the known association of employment status on these scores.

Household income levels are known to be correlated to variables such as *employment, education* and *race classification*. The significant association between household income and knowledge assessment scores has been demonstrated earlier in this chapter (*Household Income*: X^2= 89.397, p < 0.001). When considering the association of educational attainment and science knowledge assessment scores within household income groups, it becomes apparent that the role of educational attainment does not show a significant association with knowledge assessment scores at the upper income bands. Among the *moderate* and *high* household income groups, the association between educational attainment and *scientific* knowledge assessment scores was not found to be significant (*Moderate Income*: X^2= 0.119, p > 0.05; *High Income*: X^2= 5.748, p > 0.05). However, within the *low* household income group, the association between educational attainment and knowledge assessment scores was found to be highly significant (*Low Income*: X^2= 21.711, p < 0.001). This implies that while educational attainment has been shown to be significantly associated with response on knowledge assessment scores, when considered with household income level, its influence is only significant at the lower end of the income scale.

Conclusion

Survey results for the scientific knowledge assessment indicates that an average of 40.3% of South Africans were able to provide scientifically correct responses. This result implies that the overall level of scientific literacy among the sample was generally low. Within the 3 486 respondents, an average of 59.7% of respondents provided a *scientifically incorrect* or *don't know* response. This low level of scientific literacy is indicative of a general lack of knowledge with respect to the 9 science-subject areas included within this research.

At the aggregate level, South Africans appear to be more knowledgeable in areas related to *medical science* (*HIV and genetics*) as well as *physical science* (*geology*) having attained the highest proportion of scientifically correct response within these items. The areas demonstrating the lowest overall correct response were related to the subject areas of *psychology* and *astronomy*. The majority of respondents were not able to correctly identify the main purpose of the *Square Kilometre Array* Telescope (SKA) or relate the difference between two distinct psychological disorders within these questionnaire items. These items similarly produced the highest d*ifficulty index* rating, indicating the majority of respondents were not able to respond to these items correctly (see appendix 2).

Demographic classifications revealed some notable outcomes within the science knowledge assessment items. *Race* demonstrated a highly significant impact on overall results to this question set. A greater proportion of white and Indian / Asian respondents were able to provide correct responses compared to coloured and black respondents. Respondents within the black sub-sample provided the lowest overall proportion of correct response. This was particularly notable among respondents within the senior age classifications. Related to this, black and coloured respondents were more likely to acknowledge a *knowledge gap* by selecting a *don't know* response, rather than provide a scientifically incorrect response, when compared to white and Indian / Asian respondents.

White respondents performed significantly better within the item related to *climate change* (+20.3% above the national average), while Indian / Asian respondents performed best at items related to *psychology* (12.0% above the national average).

Gender was found to be statistically significant within response to individual items in the question set. However, despite this, the proportions of scientifically correct response for females (39.3%) and males (41.3%) did not demonstrate large variation. Within *race* classifications, males and females did not display statistically significant variations in their response proportions, however across *race* groups the expected variations were observed. Similar patterns were revealed within *employment*, *income*, *education* and other socioeconomic variables, indicating the interacting influences these variables may have on the scientific knowledge assessment scores with respect to gender. While there remain valid concerns around the role of gender with regards to the overall levels of scientific literacy within the South African population, response patterns for females and males, in isolation from other demographic variables, indicates a closing gap between gendered outcomes on assessments of scientific knowledge.

The geographic location of respondents demonstrated a profound influence on science knowledge assessment scores. Urban respondents revealed higher proportions of correct response compared to rural respondents. Black respondents within rural areas were significantly more likely to provide fewer correct responses compared to their urban counterparts. Among both males and females, no significant difference was reported within urban / rural location groups. However, across location categories, urban respondents generally perform better than rural participants, irrespective of gender classification. Location group classification showed a significant association with knowledge assessment scores for respondents with *low* and *moderate* income; however this was not the case within the *high* income group. Educational attainment reflected a comparable pattern, wherein rural respondents with a lower level of education were shown to report significantly fewer correct responses on the knowledge items, compared to those within urban areas. The level of respondent *educational attainment* and *household income* was found to be significantly associated to scientific knowledge assessment scores when compared to the rural / urban location of respondents.

Respondents with increased education similarly presented more frequent correct responses compared to those with lower educational attainment. Interestingly, for white and Indian / Asian respondents no statistically significant association was shown between educational attainment and response to the knowledge assessment items. However, among black and coloured respondents, a significant association was demonstrated for those with increased educational attainment levels. Males and females with similar educational attainment did not exhibit a statistically significant variation on the knowledge assessment outcomes. However, across gender groups, the influence of educational attainment level displayed a highly significant association with knowledge assessment scores. Respondent level of education was found to be particularly significant within the *low* income group; however this influence is not as significant within *moderate* and *high* income households.

The influence of respondent employment and levels of household income demonstrated similarly significant associations to the scientific knowledge assessment score. Respondents indicating employment, similarly report higher knowledge assessment outcomes. This was particularly notable within the black and coloured respondents, for those employed compared to those within the remaining two employment classifications. Employed men generally provide more correct responses, compared to other men. However, the association between gender and employment status was not recorded among the female sub-sample. Rural respondents reporting employment achieved higher knowledge assessment scores compared to other rural respondents; however, no notable variation in scores was recorded within the urban sub-sample for employment status. Household income level revealed a significant association with knowledge assessment scores, where respondents within higher household income groups generally provided a greater proportion of correct response. Within the black, white and coloured sub-samples, the association between household income and scientific knowledge assessment scores was found to be statistically significant. However within the Indian / Asian sub-sample no such association was statistically substantiated. Gender groups showed similar patterns of increased scientific knowledge within increased household income. This was particularly notable within the *high* income group, where a statistically significant association was identified, with males generally providing a higher proportion of correct response compared to females.

Chapter Six

Descriptive Survey Results:

Attitudes to Science

The scientific attitude of mind involves a sweeping away of all other desires in the interest of the desire to know.

Bertrand Russell (1919)

Introduction

The study of *attitudes to science* has not been without contestation over the preceding 50 years of research (Bauer, Durant & Evans; 1994, Allum, Sturgis & Tabourazi; 2008). Much debate has centred on definitional issues as well as discussions relating to which aspects of attitudes should be measured – be it the structure of attitudes, attitude formation, attitudinal change or the attitude-behaviour relationship. A key point that has emerged within reviewing the literature on attitudinal measurement and specifically the measurement of *attitudes to science* is the distinction between *"scientific attitudes"* and "*attitudes to science*" (Gardner, 1995). The initial idea relates to a complex series of innate beliefs and behavioural interactions within an individual and society that promotes a *healthy scepticism*, enquiring approach to information received and an ability to distinguish between appropriateness of research questions and suitability of data supporting any findings (see Gauld & Hukins, 1980 - In Osborne, 2003). Shukla (2005) has often quoted Nehru's ideas of *scientific temper* in discussing *scientific attitude* within the Indian context. The value of this concept cannot be emphasised enough and certainly adds a tremendous value to the broader objectives of research within this field of study.

However, as important as the concept of *"scientific attitudes"* are to this research and the broader discussion within the South African context, within the current research, the concept under consideration relates specifically and exclusively to "*attitudes to science*". In its simplest, an attitude is "a relatively enduring organization of beliefs, feelings, and behavioural tendencies towards socially significant objects, groups, events or symbols" (Eagly, & Chaiken, 1993). The measurement of *attitudes to science* (within this context) relies on being able to efficiently access these *beliefs and feelings* with respect to science, and quantify them in an accessible yet transparent manner. Here the strength (how enduring the attitude is) and the direction (positive or negative attitudes) are important considerations and will continue to be the focus within this investigation.

Within this research, the question being considered is, *do South Africans demonstrate positive or negative attitudes to science within a social context?* This includes gaining an understanding of the value South Africans attach to *science in daily activities*, the role of science in *shaping a future society* as well as an indication of *public risk perception* associated with scientific advancement. These questions do not target any branch of science or any specific scientific concepts, but rather seeks to understand the public perception and contribution of science to ordinary South Africans. As a broad research project, non-specific to attitudes, this study is only focusing on the *cognitive* component of attitudes. This cognitive aspect focuses on the personal *knowledge* and *belief* people associate with particular attitude objects (Ostrom, 1969). While this will not illuminate attitudes to science in every detail it will provide valuable insight into the direction and strength of attitudes held by the general South African public, with regards to the contribution of science within the social landscape.

OVERALL NATIONAL RESULTS FOR ATTITUDES TO SCIENCE ASSESSMENT ITEMS[104]

Items that were designed to convey a positive scientific sentiment (item 1 and 3) attracted the highest proportions of *agree* response. These are items designed to access public attitudes of support; belief in the promise of science and its value to society. The majority of respondents (68.7%) agreed with Item 1 (s*cience and technology are making our lives healthier, easier and more comfortable*); while 10.8% expressed disagreement and 20.5% selected the neutral (*neither agree nor disagree*) response option. Within Item 3, a larger share of respondents (71.9%) agreed that *thanks to science and technology, there will be more opportunities for the future generation*, while 9.8% disagreed and 18.3% selected the neutral option.

Items that are considered *critical* with regards to science may provide insights into the level of perceived public risk; general reservation; lack of public trust, support or related value-driven influences within the public mind-set. Among these items, item 2 and item 4 were responded to as follows. The majority of respondents (47.5%) agree with the attitudinal statement *it is not important for me to know about science in my daily life*, while 30.2% disagreed and 22.3% opted to select the neutral option. Results for item 4, despite being phrased with a sentiment *critical* to science, reflected a significantly higher proportion of *agreement* (68.8%) compared to item 2, while 11.7% disagreed and 19.5% indicated that they *neither agree or disagree* with the statement (see chart 6.1).

[104] The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

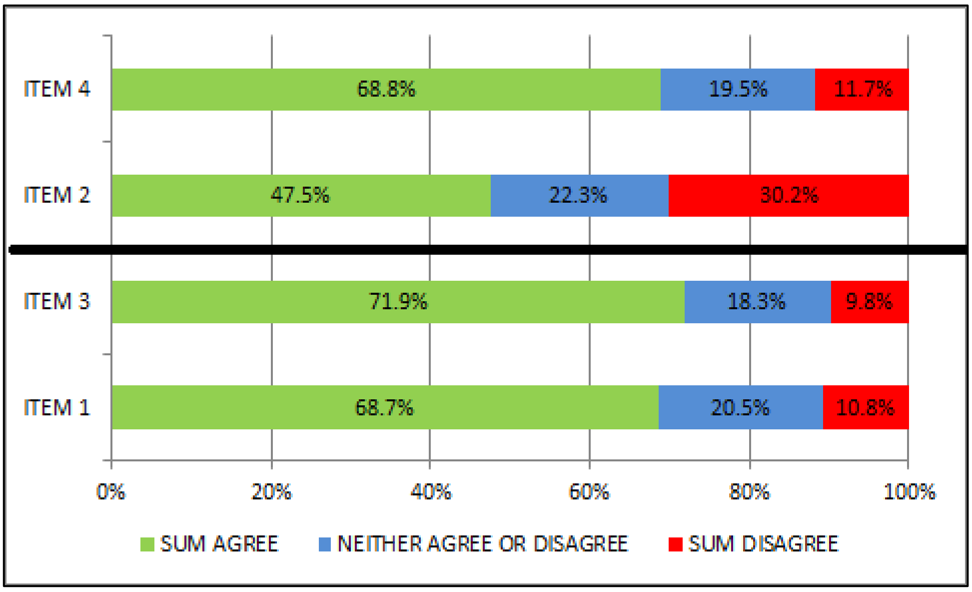


Chart 6.1: Overall result: South African *Attitudes to Science* assessment % (Khayabus wave 2, 2015)

Discussing the results of the attitudes to science assessment, it would be conceptually valuable to begin to refer to the four items within groups that would reduce the complexity of the discussions to follow. As such, items 1 and 3, as they are imbedded with a *positive* scientific outlook will be considered *scientific promise* items, while item 2 and 4, having a more *critical* position would be considered items of *scientific reservation*.

Within this updated classification of the four questionnaire items, one is able to make an assessment of the general attitudes held by South Africans with regards to science in a social context. There appears to be a general agreement to *scientific promise* items, with an average of 70.3%[105] of the sample selecting an *agree* or *strongly agree* response at both p*romise* items. The majority of respondents within this survey have an affinity to a belief in the positive *contribution of science to daily life*, while also adopting a common confidence in the *future value of science* within South African society. Juxtaposed to these general positive views of science, is a common sense of concern wherein an average of 58.2%[106] of respondents expressed a level of apprehension in providing agreement with the *scientific reservation* items.

A commonly used index, adopted by many studies on the *public understanding of science* is called the *Index of Scientific Promise and Reservation* (see chapter 3). Through the use of attitudinal statements, similar to the ones adopted in this study, two indices are created, one for the measurement of *scientific promise* and the other for the measurement of *scientific reservation*. The scores for each index are then used to calculate a ratio between the two indices, producing the *Index*

[105] Average across agree responses to Item 1 and Item 3
[106] Average across agree response to Items 2 and Item 4

of Scientific Promise and Reservation. Within these indices higher scores indicate *agreement* with the attitudinal statements while lower scores indicate *disagreement* with the statement.

The *promise* and *reservation* indices are calculated by aggregating all responses of '*strongly agree'* or '*agree'* and dividing this by the number of items constituting the respective index[107]. According to Reddy *et al* (2013), "*the average promise score is divided by the average reservation score to provide a single promise-reservation ratio of attitudes towards science – in which a higher score indicates a generally more positive attitude* [to science]" (pp 3). This ratio ranges between 0.00 till +2.00, wherein scores below a 1.00 value indicates *general negative attitudes* to science and values above 1.00 *general positive attitudes* to science. Scores from each question were extracted using *IBM SPSS 24.0* and *Microsoft Excel* employing frequency distributions toward developing the individual scores for each of the indices. The individual scores were then incorporated into the calculation of the total score for this *Index of Scientific Promise and Reservation*.

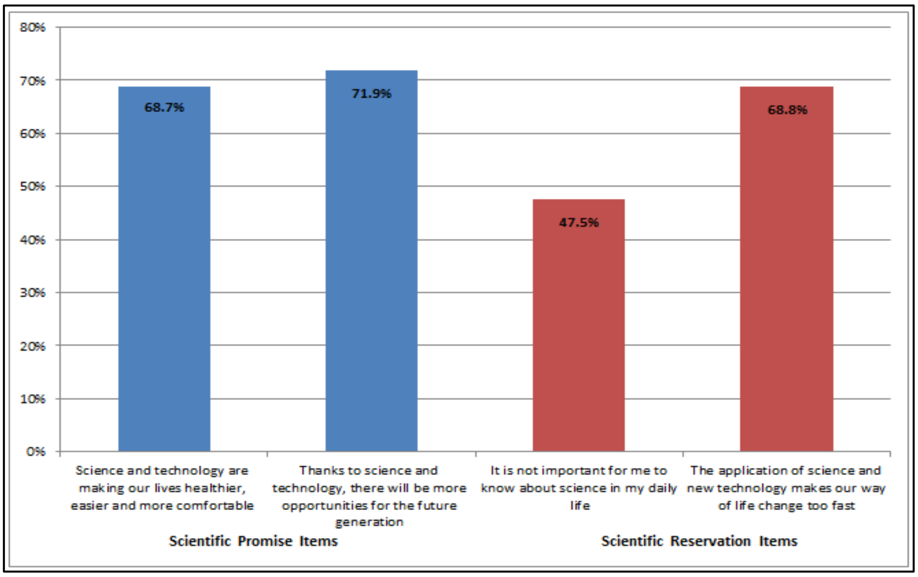


Chart 6.2: South African *Attitudes to Science* assessment: Promise & Reservation (Khayabus Wave 2, 2015)

Results from the four items are presented in chart 6.2 (above) as *promise* and *reservation* scores. Scores for each *promise* and *reservation* index are arrived at through calculating the proportion of those presenting an *agree* response (*strongly agree* and *agree*) to the total number of responses within that item. The calculation of the in*dex of promise and reservation* is demonstrated in below.

[107] A methodological point should be noted here as the present study adopted a 4-item question set, as per Bann & Schwerin (2004) and Shukla & Bauer (2009). This deviates from the traditional 7-item index used by Reddy *et al* and others (see chapter 3). This was adopted as a result of methodological equivalency of the 4-item question format demonstrated by Bann & Schwerin (2004) as well as the cost considerations when implementing a nationally representative survey sample.

	Attitudinal Statement	SUM AGREE	% total N	Agree %	N	
Item 1 (P)	Science and technology are making our lives healthier, easier and more comfortable	2246	0.69	0.70	3269	1.21
Item 3 (P)	Thanks to science and technology, there will be more opportunities for the future generation	2351	0.72		3271	
Item 2 (R)	It is not important for me to know about science in my daily life	1560	0.48	0.58	3281	
Item 4 (R)	The application of science and new technology makes our way of life change too fast	2247	0.69		3265	

Table 6.1: South African Attitudes to Science: Calculation of *Index of Promise & Reservation*

Within the 2015 Khayabus survey module data, the average *Promise Index* score was calculated to be 0.70, while the average *Reservation Index* score was slightly lower, at 0.58, yielding a *Promise-Reservation Index* ratio of 1.21 (table 6.1). This leads to the finding that, despite some reservations, in general, the South African public demonstrates a positive attitude toward science and its contribution to society.

Comparison of the present Khayabus survey module data with the most recently available data from the HSRC – SASAS series is presented in chart 6.3.

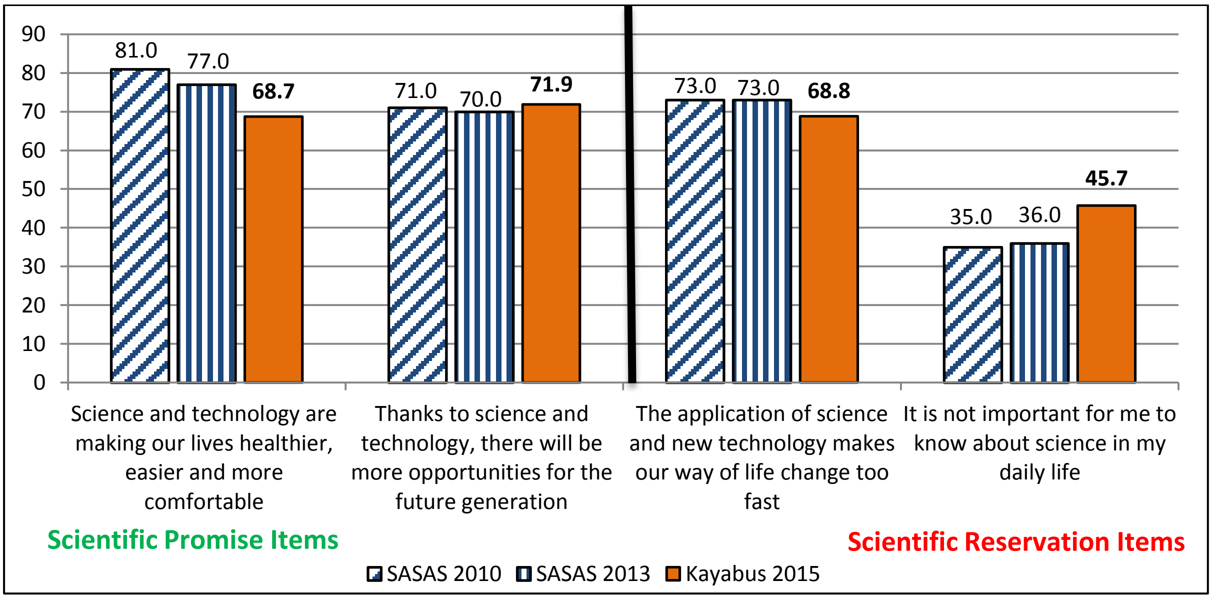


Chart 6.3: South African Attitudes - *Index of Promise & Reservation*: comparison to HSRC-SASAS data

Noting the previously mentioned methodological variations between the research instruments; all four items were common to each of the above mentioned surveys. Despite the lower scores within the Khayabus survey data (2015), the general result is comparable across all 3 data sets and survey years. In the Khayabus survey, while positive in their attitudes to science, respondent reported a lower general agreement within the scientific promise items. This appears to be consistent with the decreasing level of *scientific promise* among the South African public since 1999. As an example, in the 1999 the *Evaluation of Public Opinion* survey[108] respondents reported 82% agreement with the statement "*Science and technology are making our lives healthier, easier and more comfortable*".

[108] Precursor to the current *South African Social Attitudes Survey* (SASAS)

Since then, in the 2010 SASAS survey, this dropped to 81% while in the 2013 SASAS survey the reported figure was 77% (Reddy *et al*, 2015). Similarly for the scientific reservation items, while these values appear consistent with reported values in the previous SASAS surveys, the Khayabus results do indicate a decrease compared to previous results. The item, "*The application of science and new technology makes our way of life change too fast*" received an agreement value of 68.8% in the Khayabus 2015 survey, while in the 2 preceding SASAS surveys this item attracted marginally higher reservation score in both 2010 and 2013. Results for the reservation item, "*It is not important for me to know about science in my daily life*", within the Khayabus survey yielded a 45.7% agreement, however, in the 2 preceding SASAS surveys this result was much lower (see chart 6.3). The recorded increases in negative attitudes since 1999, concerning self-reported overall appreciation of science is noted and remains of concern.

In reviewing comparison across multi-national data[109], South Africa's general positive attitudes to science (1.21) compares favourably with our international counterparts (see chart 6.4). The comparison includes results from European surveys (1.41) as well as the United States of America (1.72). India as a developing country, and a member of the BRICS collective, scored 0.80 on the *index of promise and reservation*, however it should be noted that this result is from the 2005 Indian survey, prior to a major economic upswing within India during the interim period. The results from the 2015 Khayabus survey compare favourably to the SASAS 2013 survey results, despite the slight decline in the ratio since the 2001 measurement by Blankley and Arnold.

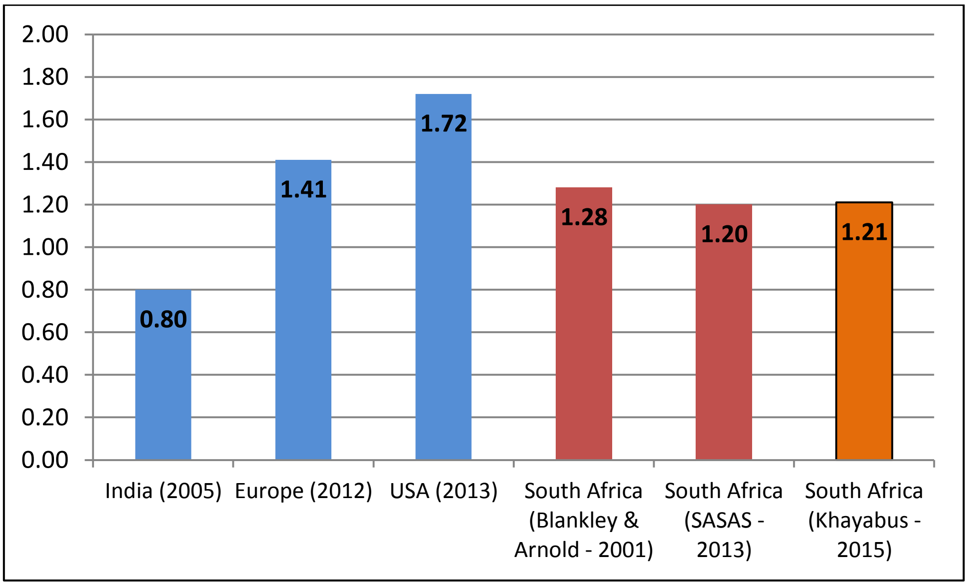


Chart 6.4: South African Attitudes - *Index of Promise & Reservation*: International comparison

[109] Periodicity of data availability for multi-national comparison remains a challenge to comparative analysis

An additional method of understanding attitudinal scales was developed for this study and takes a further factor into account when trying to understand this attitudinal data. The attitudinal scales developed for questions of this nature have traditionally included five response selection points - from *strongly agree* to *strongly disagree*. Within a conventional *index of promise and reservation* (see above), scores for the *agree* categories are taken into account, while the scores for the *neutral* and *disagree* categories are not operationalised within this measure. This produces a snapshot of agreement to selected attitudinal statements, both positive and negative and offers research a ratio between these levels of agreement.

This approach does not take into account the potential influence of *attitudinal ambivalence* among the sample, across the attitudinal statements in the questionnaire. *Attitudinal ambivalence* relates to the idea that individuals or groups of individuals may have simultaneous, yet conflicting attitudes toward the same subject or attitude object. While attitudes generally have an influence on behaviour (positive or negative), *attitudinal ambivalence* often moderates this influence on behaviour and weakens the attitudes propensity to direct behaviour. An example of this is physical exercise – most people would agree that a daily workout routine is beneficial to the body and mind. However many people, despite this generally positive attitude to exercise, still do not maintain a regular training schedule. Further to this, ambivalent attitudes are also more malleable when individuals encounter additional information on a subject matter and are likely to undergo short-term behaviour changes as a result, which may not be sustainable or beneficial in the long term (*crash-diets* or "home work-outs" are some examples).

The above relates well to the study of attitudes to science within the developing world. In bridging the developmental divide (discussed in chapter 1) science and technology has a massive role to play toward accelerating social and economic development. However, if attitudes to science (and technology) are not conducive toward fostering positive behavioural and social outcomes, this may impact any potential benefits to society. As a result, ambivalent attitudes to science are not desirable as these are often susceptible to rapid changes upon encountering additional information (even if non-factual) due to the relative low resilience of ambivalent attitudes. Within the evolving South African social and knowledge economy context, the influence of ambivalent attitudes to science may be an important consideration from a policy and planning perspective and offers a novel way of approaching many questions surrounding attitudes to science.

Within the current dataset, it is noted that individuals may be supportive of positive scientific advancements while simultaneously averse to any potential risks that it may pose. It should be noted that a reasonable level of risk aversion is required toward more stable and grounded attitude formation, be it a supportive or critical attitude. However attitudinal ambivalence is highlighted as a particular threat toward forming meaningful and healthy altitudes to science. This crossroad however, concurrently presents an *opportunity* to identify any indication of attitudinal ambivalence, with particular reference to how the public values and engages with science. The result from within the Khayabus survey is again presented in table 6.2 below.

Attitudinal Statement	STRONGLY AGREE	AGREE	**NEITHER AGREE OR DISAGREE**	DISAGREE	STRONGLY DISAGREE
Item 1 (Promise 1)	31.0%	37.7%	**20.5%**	7.1%	3.7%
Item 2 (Reservation 1)	18.6%	29.0%	**22.3%**	18.6%	11.6%
Item 3 (Promise 2)	30.9%	41.0%	**18.3%**	6.1%	3.7%
Item 4 (Reservation 2)	30.1%	38.7%	**19.5%**	7.6%	4.1%

Table 6.2: Percentage scores recorded for all valid responses to the *attitudes to science* question set

The response data indicates an average of 20% of respondents adopted the *neutral* (*Neither Agree or Disagree*) response option within all four survey items. In order to assess the level of ambivalence within the sample a *measure of attitudinal ambivalence* was developed and applied to the attitudinal dataset. The *measure of attitudinal ambivalence* was designed as an indirect measure to examine *global ambivalence* and not necessarily the difference between the cognitive and behavioural evaluations of attitudes – due to the type of data available within this study.

The approach adopted in producing the *measure of attitudinal ambivalence* adapted a data structure using the 5-point coding option discussed in table 6.3. Within this coding option, the five response options in the promise items are coded from +1 to -1 (*strongly agree* to *strongly disagree*) and this coding is reversed for the reservation items. *Don't know* responses are regarded as *invalid*.

PROMISE ITEMS (1 & 3)					
STRONGLY AGREE	**AGREE**	**NEUTRAL**	**DISAGREE**	**STRONGLY DISAGREE**	**DK**
1	0.5	0	-0.5	-1	8

RESERVATION ITEMS (2 & 4)					
STRONGLY AGREE	**AGREE**	**NEUTRAL**	**DISAGREE**	**STRONGLY DISAGREE**	**DK**
-1	-0.5	0	0.5	1	8

Table 6.3: Attitudinal items recoding structure

The revised coding structure was then applied to the dataset and a new variable was created to *sum* the scores across all four recoded attitudinal items. A *SUM_ATTITUDE* score was produced for each respondent as a result of the net-sum of the positive and negative scores attained across all four items. The sum score range is between -4.0 to +4.0 as a result of the coding structure applied and the number of items in the attitude scale. Within this score, a positive value reveals a greater positive attitude, while a negative value is indicative of a more negative attitude across the four questionnaire items. A resultant net-sum-score of zero (0) is indicative of a degree of *attitudinal ambivalence*, implying that across both the promise and reservation items, respondents report conflicting attitudes (agree / disagree with promise and reservation items). This sum attitude score was then used to create the *measure of attitudinal ambivalence* by observing the score frequencies across all items for each respondent. The result of this analysis is presented in table 6.4 below.

	SCORE	N	% of N	
more Critical attitudes	-4.0	0	0.00%	**18.40%**
	-3.5	0	0.00%	
	-3.0	2	0.10%	
	-2.5	9	0.30%	
	-2.0	19	0.50%	
	-1.5	48	1.40%	
	-1.0	177	5.10%	
	-0.5	386	11.10%	
	0	**1 384**	**39.70%**	**39.70%**
more Positive attitudes	0.5	548	15.70%	**41.90%**
	1.0	420	12.00%	
	1.5	232	6.70%	
	2.0	204	5.90%	
	2.5	39	1.10%	
	3.0	12	0.30%	
	3.5	2	0.10%	
	4.0	4	0.10%	
		3 486	100.00%	

Table 6.4: Result of computation for the *measure of attitudinal ambivalence*

At an aggregate level, for scores across all questionnaire items, taking agreement, disagreement and neutral responses into account, the majority of South Africans appear to be more positive in their general attitudes to science. The data reveals that 18.40% of respondents reported a greater *critical attitude* toward science, while 41.90% of respondents achieved a positive sum attitude score indicative of greater positive attitudes to science (see table 6.4). Between these results however is a large group of individuals (39.70%) that across both the scientific promise and reservations items report a degree of attitudinal ambivalence. This is indicative of these respondents demonstrating little differentiation between responses to *promise* and *reservation* items.

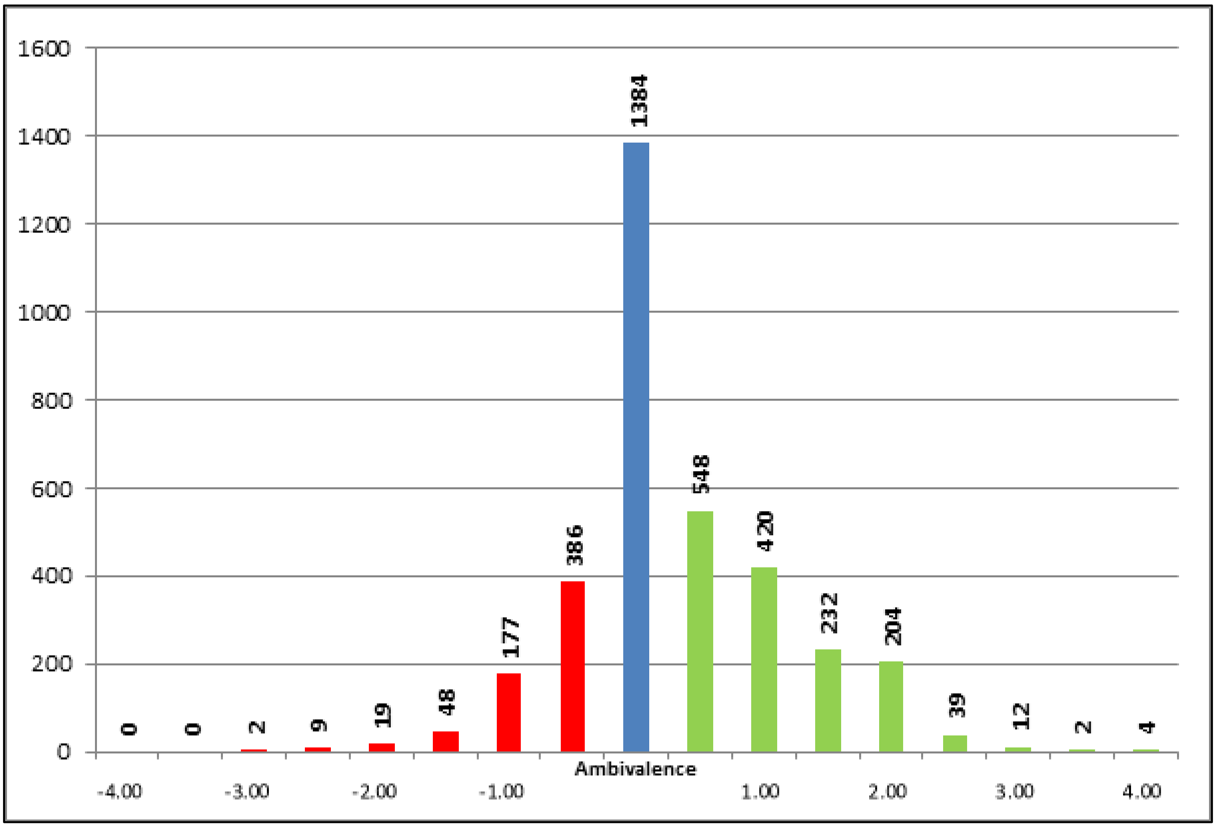


Chart 6.5: Attitudes to Science: *Measure Of Attitudinal Ambivalence*

Chart 6.5 presents the number of respondents falling within each response category. This is an indication of general South African public demonstrating predominantly positive attitudes to science, however aware of the social risks associated with scientific achievements. This equates well with the value of 1.21 calculated for the South African *Index of Promise and Reservation*, earlier in this chapter. Within the *Index of Promise and Reservation*, a score between 1.00 and 2.00 implies greater agreement to the *promise of science*. The score of 1.21 calculated for the South African *Index of Scientific Promise and Reservation*, therefore indicates a greater degree of *scientific promise* attitudes, and is consistent with the results of the *measure of attitudinal ambivalence* (above).

The salient factor within the *measure of attitudinal ambivalence* is the large proportion of respondents reporting potentially ambivalent attitudes to science (39.7%). As discussed earlier, attitudinal ambivalence is less desirable, particularly with regards to its relationship with attitudes to science. A key consideration here is the influence that ambivalence has on overall attitude formation and stability over time. The influence of attitudes and attitudinal ambivalence may be an important consideration to the overall public understanding and engagement with science. Attitudinal ambivalence has a noted influence on malleability of attitudes over time and how new information is received and acted upon by individuals and society. Strategically, it would be in the interest of the individual as well as those interested in science policy to foster strong attitudes to science, rooted in factual foundations – irrespective if these attitudes are positive or critical of science. Reducing the level of attitudinal ambivalence would be particularly important within the South African setting, in light of the strategic importance of science and technology to current and planned socio-economic transformation programs.

Overall levels of attitudes to science are presented in table 6.5 and will be followed by a detailed assessment of each demographic variable.

*Average VALID response	Scientific Promise Items			Scientific Reservations Items			
	AGREE	NEUTRAL	DISAGREE	AGREE	NEUTRAL	DISAGREE	N
NATIONAL	**65.9%**	**18.2%**	**9.7%**	**54.6%**	**19.6%**	**19.7%**	**3 486**
RACE	N = 3 486						
BLACK	64.8%	18.2%	9.8%	55.5%	19.4%	18.2%	**2 523**
WHITE	72.3%	17.4%	9.4%	54.8%	19.1%	25.2%	**408**
INDIAN / ASIAN	58.3%	19.8%	19.0%	47.9%	22.3%	27.3%	**121**
COLOURED	68.4%	18.4%	6.3%	51.2%	20.3%	21.1%	**434**
GENDER	N = 3 486						
FEMALE	65.5%	18.1%	9.0%	54.8%	18.9%	19.0%	**1 747**
MALE	66.3%	18.3%	10.3%	54.4%	20.3%	20.4%	**1 739**
GEOGRAPHIC LOCATION	N = 3 486						
URBAN	68.4%	17.9%	8.9%	55.8%	19.5%	20.1%	**2 297**
RURAL	61.2%	18.8%	11.1%	52.4%	19.8%	18.8%	**1 189**
EDUCATION	N = 3 486						
PRE-MATRIC	60.3%	19.4%	9.4%	50.5%	19.9%	18.9%	**1 369**
MATRIC COMPLETED	68.8%	17.5%	10.4%	57.2%	19.5%	20.0%	**1 578**
POST-MATRIC	71.8%	17.3%	8.0%	57.3%	19.3%	20.7%	**539**
AGE	N = 3 472						
<20 YEARS	72.1%	16.8%	8.8%	60.9%	19.1%	17.9%	**170**
20-29 YEARS	67.3%	18.0%	10.5%	55.2%	19.1%	21.3%	**1 101**
30-39 YEARS	67.9%	17.5%	9.4%	55.5%	19.8%	19.8%	**956**
40-49 YEARS	66.2%	18.0%	9.5%	55.6%	20.4%	17.6%	**598**
50-59 YEARS	64.1%	18.0%	7.8%	52.4%	19.0%	18.8%	**372**
60+ YEARS	51.3%	23.8%	10.2%	45.5%	20.9%	19.1%	**275**

Table 6.5: Results of Attitudes to *Science* by demographic classifications in Khayabus wave 2, 2015

There was a significant difference in the attitudinal response patterns of respondents from different race-based sub-samples (X^2=19.666, p < 0.01). White respondents (72.3%) more often agreed with scientific promise items compared to coloured (68.4%); black (64.8%) and Indian / Asian (58.3%) respondents. The variation among race groups is not as large within the items of scientific reservation. White respondents displayed a higher propensity to agree with scientific reservation items (54.8%) compared to black (55.5%), coloured (51.2%) and Indian / Asian (47.9%) participants. Compared to the proportion of *agree* responses, the *neutral* and *disagree* options were selected more often within the scientific reservation items (item 2 and item 4). Further to the above, within the scientific promise items, respondents were more inclined to select the *neutral* response over the *disagree* response, compared to the response patterns in the scientific reservation items.

Overall response, by *gender* groupings did not demonstrate a statistically significant association with the overall population performance within the attitudes to science items (X^2=16.121, $p > 0.05$). The average proportion of *females* agreeing with the scientific promise items was 65.5% compared to 66.3% recorded for male participants (n = 3 486). Response to scientific reservation items yielded a similar pattern, where male (54.4%) and female respondents (54.8%) offered comparable levels of agreement. Within both promise and reservation items, females and males did not reveal any significant variation in *neutral* and *disagree* responses. Despite this, within the scientific reservation items the selection of the *neutral* and *disagree* responses were higher than among the items of scientific promise for both genders. This may be indicative of the likelihood that attitudes to science in South Africa may not be directed exclusively by gendered variance as much as other aspects of the general public understanding of science.

The role of geographic location was assessed within each of the South African provincial demarcations as well as by the rural / urban classification. Analysis of the overall response to attitudinal items by province showed a statistically significant difference in the recorded scores (X^2=301.952, $p < 0.001$). This outcome may not be as a direct result of the influence of provincial location, however may be due to the influence of interrelated socio-demographic variables moderating this recorded response. The response variation on the attitudes to science measure by rural / urban classification was not found to be statistically significant (X^2=14.147, $p > 0.05$). Details of these variations within geographic location classifications will be addressed in greater details in the following sub-section.

Respondent *educational attainment* was found to be a significantly associated with attitudinal item response (X^2=44.541, $p < 0.05$). Respondents with *pre-matric educational attainment* demonstrated a lower propensity to offer agreement to items of scientific promise (60.3%) compared to those with post-matric educational qualifications (71.8%). Response within the scientific reservation items did not deviate from the established pattern when considered with educational attainment. A greater proportion of respondents were inclined to *disagree* with items of scientific reservation, than within the items of scientific promise, though this was not entirely unexpected.

At an aggregate level, *age* of respondents did not demonstrate a statistically significant association to performance on the four attitudinal items in the questionnaire (X^2=81.761, $p > 0.05$).

EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH ATTITUDES TO SCIENCE

CHAID analysis was again employed to identify relationships between demographic variables within this research. The analysis was completed adopting the composite score across all four attitudinal items, and used the following variables within this analysis: *household income; employment; gender; race; educational attainment; geographic location (rural-urban);* and *age.*

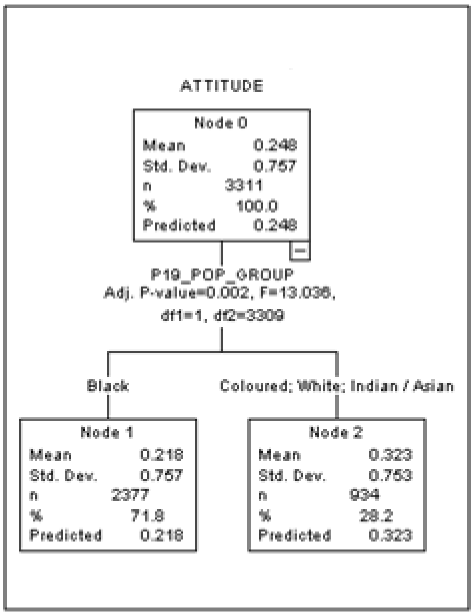


Figure 6.1: Output of CHAID analysis: Attitudes to Science

CHAID outputs revealed that only the *race* variable was found to be a suitable predictor of respondent attitude to science. Accounting for the known influence that race dynamics exert in South Africa, a step-wise elimination process was undertaken, removing variables from the CHAID analysis and observing the outcomes. After removing the *race* variable, the next most important predictor was found to be *geographic location*; however this was not the case with the reintroduction of the *race* variable. Each of these variables will be explored in some detail across the next sub-section of this chapter as well as informing the selection of the variables included within the *multinomial logistic regression* models, in a later chapter.

The following subsection of this chapter will address the above demographic variations in greater detail. The variables to be explored include: *race and geographic location*.

ATTITUDES TO SCIENCE BY RACE

A statistically significant difference was observed within the attitudinal response patterns of respondents from different race classifications (X^2=19.666, p < 0.01). Among all attitudinal items, a statistically significant association was observed for responses to attitudinal items and race group affiliation (Item 1 (P): X^2=54.942, p < 0.001; Item 3 (P): X^2=39.244, p < 0.001; Item 2 (R): X^2=41.320, p < 0.001; Item 4 (R): X^2=49.962, p < 0.001).

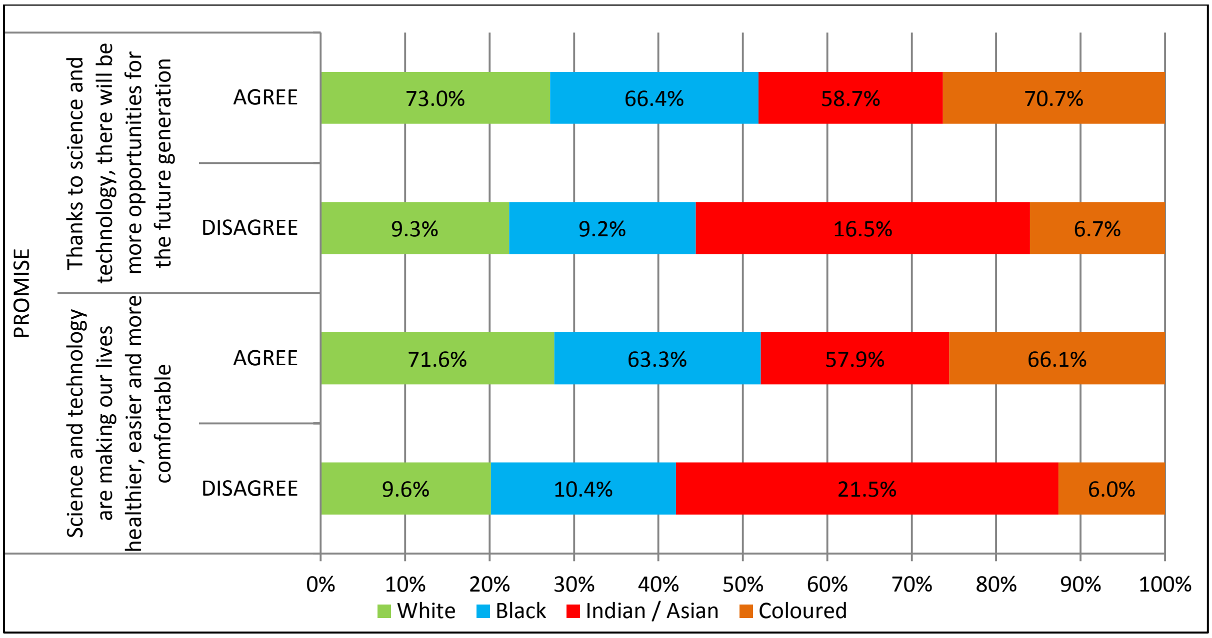


Chart 6.6: Attitudinal response to *scientific promise* items by race

Within the scientific promise items; a greater proportion of white, black and coloured respondents offered a higher agreement with the attitudinal statements. However, among Indian / Asian respondents, despite demonstrating the lowest level of agreement within these items, similarly reported the largest proportion of *disagree* response compared to their counterparts (see chart 6.6).

Reviewing the results for the scientific reservation items; the vast majority of respondents agree that the scientific advancement introduces rapid change to their way of life[110]. Similarly, a larger share of the sample across all race groups agreed that *it is important for* them *[me] to know about science in* their *[my] daily life*. However it is essential to note that the overall level of agreement within this item (Item 2) is lower than the previous scientific reservation item, yet in most cases was higher than the level of disagreement (see chart 6.7). This is not reflected among the Indian / Asian sub-sample, wherein a greater share of response (39.7%) recorded disagreement with this scientific reservation item (Item 2) compared to those offering agreement (35.5%).

[110] Item text: *The application of science and new technology makes our way of life change too fast*

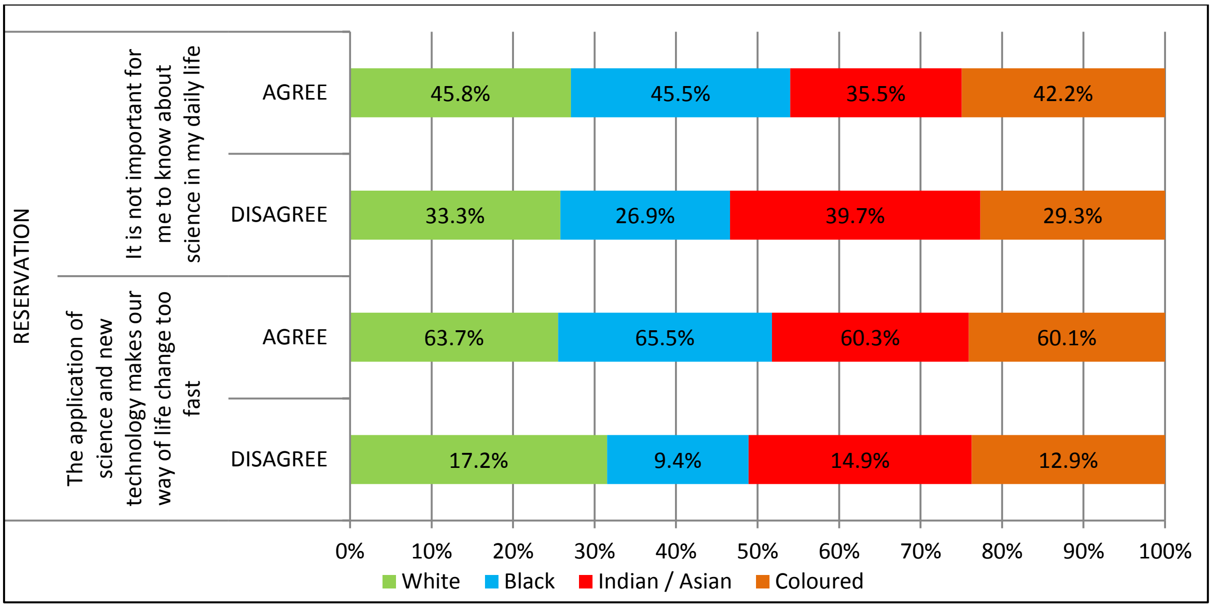


Chart 6.7: Attitudinal response to *scientific reservation* items by race

The proportion of respondents selecting a *neutral* response did not differ for black, coloured and white respondents; however the Indian / Asian sub-sample did select this option more frequently (see chart 6.7).

The earlier discussed index of scientific promise and reservation was produced for individual race group classifications and is discussed below in conjunction with chart 6.8. Within all race groups there remains an overall attitude of scientific promise; however there were noted variations across race groups for this index.

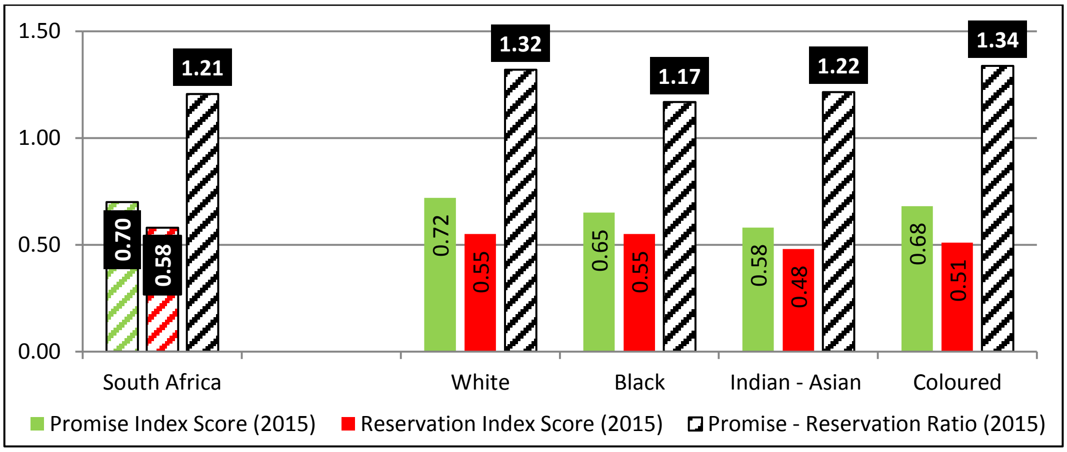


Chart 6.8: *Index Of Scientific Promise and Reservation* by race

White; coloured and Indian / Asian respondents presented a higher ratio of *scientific promise* to *scientific reservation* scores, all of which were above the value recorded for the national population (1.21). Coloured respondents achieved the highest promise-reservation index ratio of 1.34; followed by white (1.32) and Indian / Asian respondents (1.22). Among black participants this ratio was 1.17. Overall, coloured respondents achieved a promise-reservation ratio score 10.7% higher than the national average (1.21), followed by white (+9.4%) and Indian / Asian respondents (+0.7%). At the overall level, black respondents scored -3.2% compared to the national average. While this remains indicative of a greater sense of scientific promise within the black sub-sample, the lower result on this index does identify an opportunity to investigate the reasons for this attitudinal position among this sub-sample.

The degree of ambivalence within attitudes to science for the four race groups were assessed using the *measure of attitudinal ambivalence*. By race classification, coloured respondents were found to display a greater degree of positive attitudes toward science, compared to white, Indian / Asian and black respondents. Results for the *measure of attitudinal ambivalence* reflect a similar pattern of response within race groups.

Across all attitudinal items, respondents self-identifying with the *coloured* race group demonstrated the highest net-positive attitudinal score (48.8%); while 14.1% of respondents within this sub-sample achieved an attitudinal net-score within the negative range. However, among the 434 individual respondents comprising this sub-sample, 37.1% achieved an attitudinal net-score equal to zero (0), indicating a degree of altitudinal ambivalence within this cohort of the total sample (see chart 6.9).

Among the sub-sample of 408 white respondents, 48.3% achieved a net-sum attitudinal score within the positive range while 19.4% produced a score within the negative range. This share represents the largest proportion of net-sum negative attitudinal scores among all race groups. Members of the white race group attained the lowest score on the measure of attitudinal ambivalence, with 32.4% (132) of respondents achieving a net-sum score equal to zero (0).

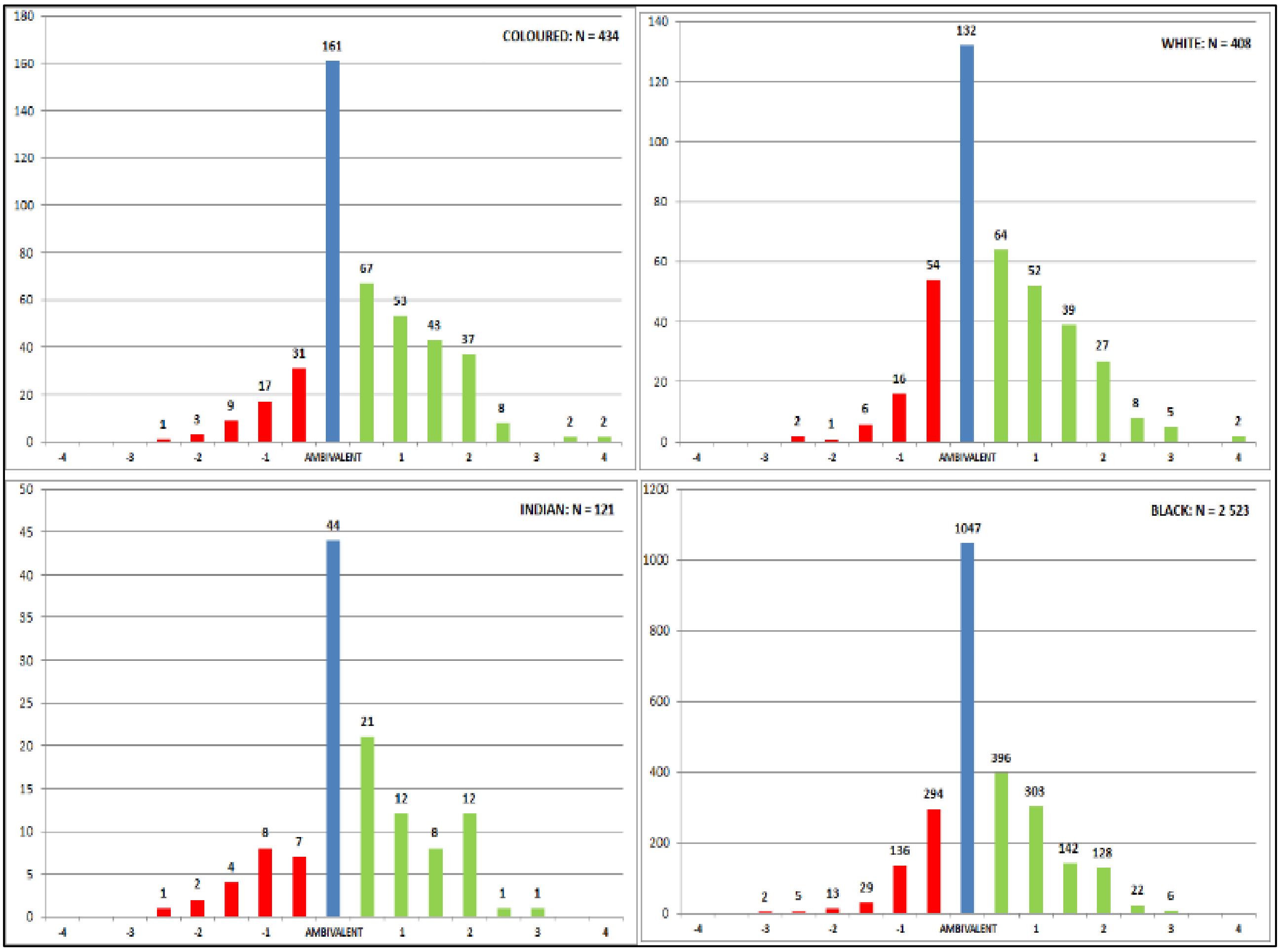


Chart 6.9: *Measure of Attitudinal Ambivalence* by race

The Indian / Asian sub-sample accounts for 3.5% of the total sample (121). While 18.2% of respondents attained a negative net-sum score, 45.5% of Indian / Asian participants demonstrated a net-positive attitude to science. Despite the smaller proportion within the sample, 44 individuals in this sub-sample (36.4%) displayed a degree of ambivalence in their reported attitudes to science.

Among the 2 523 black respondents within the sample, 39.5% demonstrated a net-sum positive attitude to science while 19.0% achieved a net negative score. Within the total sample, black respondents displayed the highest degree of attitudinal ambivalence, with 41.5% of respondents in this sub-sample (1 047) achieving this score. As black respondents constitutes 74.4% of this sample and the majority of South Africans within the population, this result highlights the importance of understanding the antecedents of attitudes to science toward developing an enhanced social environment that promotes more resilient attitudinal positions.

The above result for the *measure of attitudinal ambivalence* by race continues to exhibit a general positive attitude to science within all groups. The degree of attitudinal ambivalence presented within three of the four race groups does compare well with the overall national level of attitudinal ambivalence (39.7%). Within the race group sub-samples, white (-7.3%), Indian / Asian (-3.3%) and coloured (-2.6%) respondents all achieved attitudinal ambivalence scores below the level recorded in the national average. Respondents within the black sub-sample displayed a degree of attitudinal ambivalence +1.8% above the recorded national average for this survey. In the absence of any acceptable benchmarking values, it remains challenging to ascertain if this is indeed an area of immediate concern. Regardless of this dearth of comparative information, there remains a longitudinal concern around the influence of attitudes to science on overall public understanding and engagement activities. Furthermore the above result, across race groups remains clear evidence of the impact of race dynamics in South Africa on attitudes to science. This should receive ongoing research focus to better understand the complex of interacting variables influencing these results.

ATTITUDES TO SCIENCE BY GEOGRAPHIC LOCATION

National results indicate no significant association between rural / urban geographic location and attitudes to science (X^2=4.923, $p > 0.05$). However among each of the four attitudinal items in the questionnaire a significant association was shown between the response to the items and the rural / urban geographic location classification of respondents.

At an aggregate level, a greater proportion of urban respondents expressed agreement toward scientific promise items (68.4%), compared to rural respondents (61.2%). Similarly, fewer urban respondents elected to use the *neutral* and *disagree* response options. Scientific reservation Items were more frequently agreed to by urban respondents (55.8%) compared to rural participants (52.4%). There was a minimal proportional variance between rural and urban response to the *neutral* and *disagree* options (see table 6.5).

Significantly more urban respondents reported agreement to *scientific promise items* compared to respondents within the rural sub-sample. Within promise item 1[111], urban respondents selected the *agree* response 7.4% more frequently than rural respondents. Within the results for promise item 2[112] urban respondents selected the *agree* option 6.9% more than individuals from rural locations (Item 1 (P): X^2=31.727, $p < 0.001$; Item 3 (P): X^2=29.603, $p < 0.001$). A greater proportion of rural respondents were inclined to select the *disagree* option, compared to urban respondents. While overall, both rural and urban respondents provided a higher proportion of *agree* response to all promise items, the variations in response patterns are noted (see chart 6.13).

[111] Item text: *Science and technology are making our lives healthier, easier and more comfortable*
[112] Item text: *Thanks to science and technology, there will be more opportunities for the future generation*

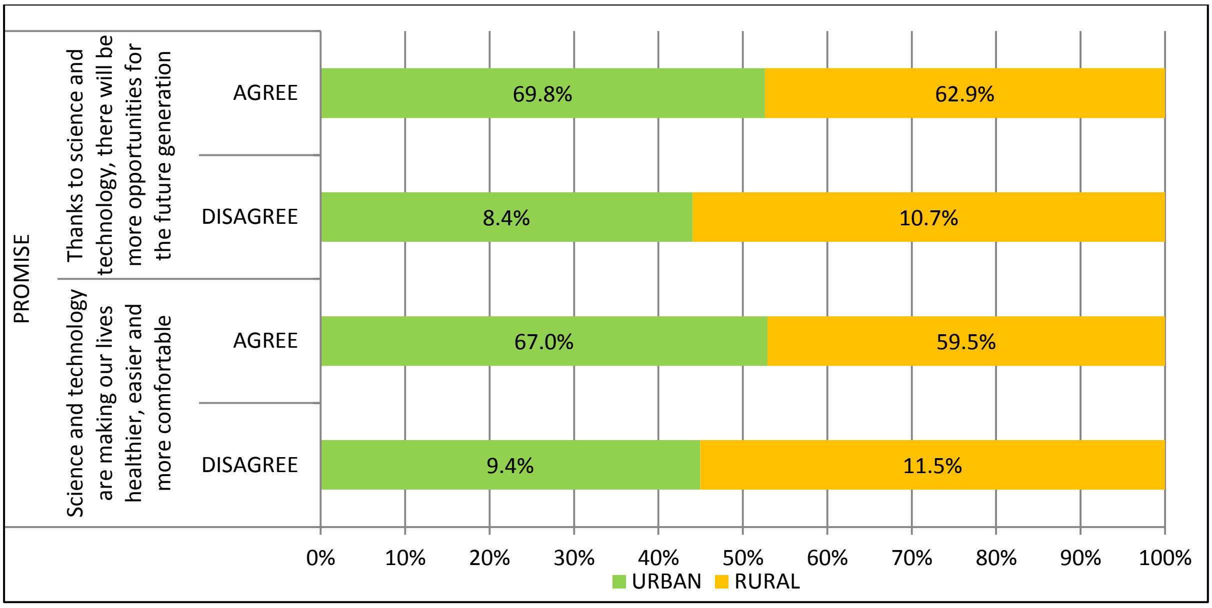


Chart 6.13: Attitudinal response to *scientific promise* items by geographic location group

Results for the two scientific reservation items are presented in chart 6.14. Responses for questionnaire item 4[113] reveals a statistically significant higher proportion of urban respondents (66.3%) indicate agreement with this statement compared to rural respondents (60.8%). A higher proportion of rural respondents indicate disagreement with this statement (11.9%) compared to urban participants (10.5%). More urban respondents (45.2%) agreed with questionnaire item 2[114] than rural respondents (43.9%). Disagreement with this item was aggregated to 25.8% of the rural population while 29.7% of urban respondents disagreed with this statement (Item 2 (R): X^2=29.995, $p < 0.001$; Item 4 (R): X^2=29.225, $p < 0.001$).

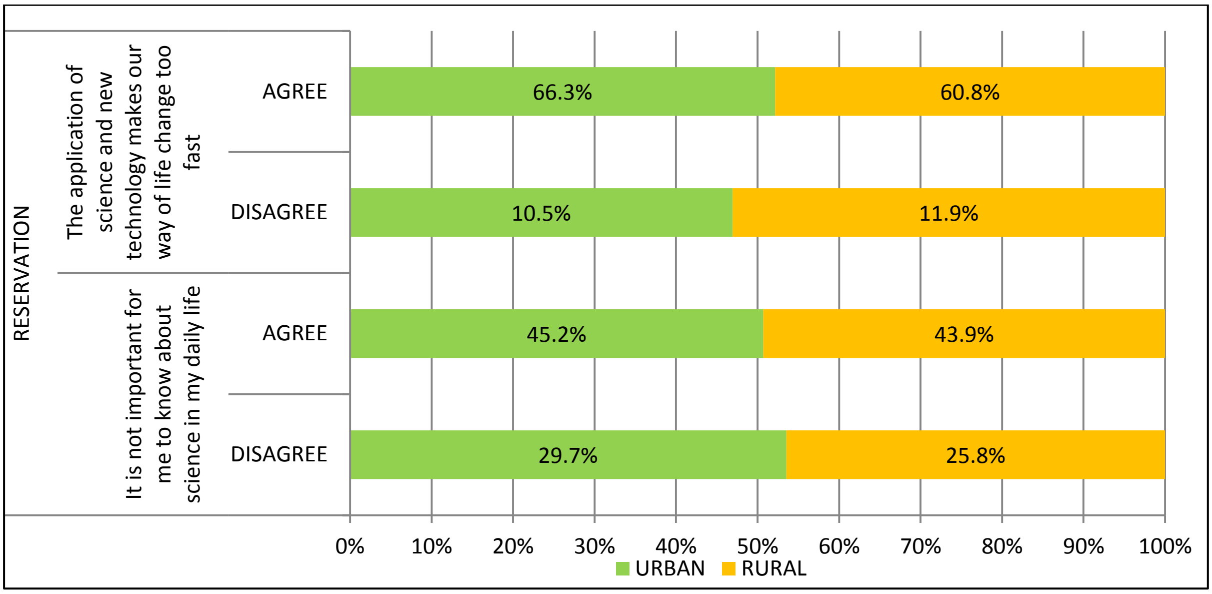


Chart 6.15: Attitudinal response to *scientific reservation* items by geographic location group

[113] Item text: *The application of science and new technology makes our way of life change too fast*
[114] Item text: *It is not important for me to know about science in my daily life*

Across all attitudinal items, responses within the *neutral*[115] category averaged to 19.0%. Item 2 attracted the highest proportion of neutral responses among all the items in the question set, with 20.7% of urban respondents and 21.5% of rural respondents providing this response. Rural respondents were more likely to select the *don't know* response option, with average selection being 2.8% higher than for the urban sub-sample.

The overall level of scientific attitudes was assessed for the rural / urban geographic location groups using the index of scientific promise and reservation. Chart 6.15 illustrates the general attitudes to science within both urban and rural sub-samples alongside the national average.

The outputs for the indices of scientific promise and reservation among both the urban and rural sub-samples indicate a lower level of scientific promise among rural respondents, while a higher level of scientific reservation within the urban sample. This resulted in the urban sample achieving a ratio of scientific promise to scientific reservation of 1.23, while rural respondents achieved a ratio of 1.17. This indicates that urban respondents within this study are more likely to demonstrate stronger attitudes of scientific promise compared to their rural counterparts. It should however be noted that the value for the rural index of 1.17 is still indicative of greater overall attitudes of scientific promise, however it remains lower than the value among the urban sub-sample and that of the national average (1.21).

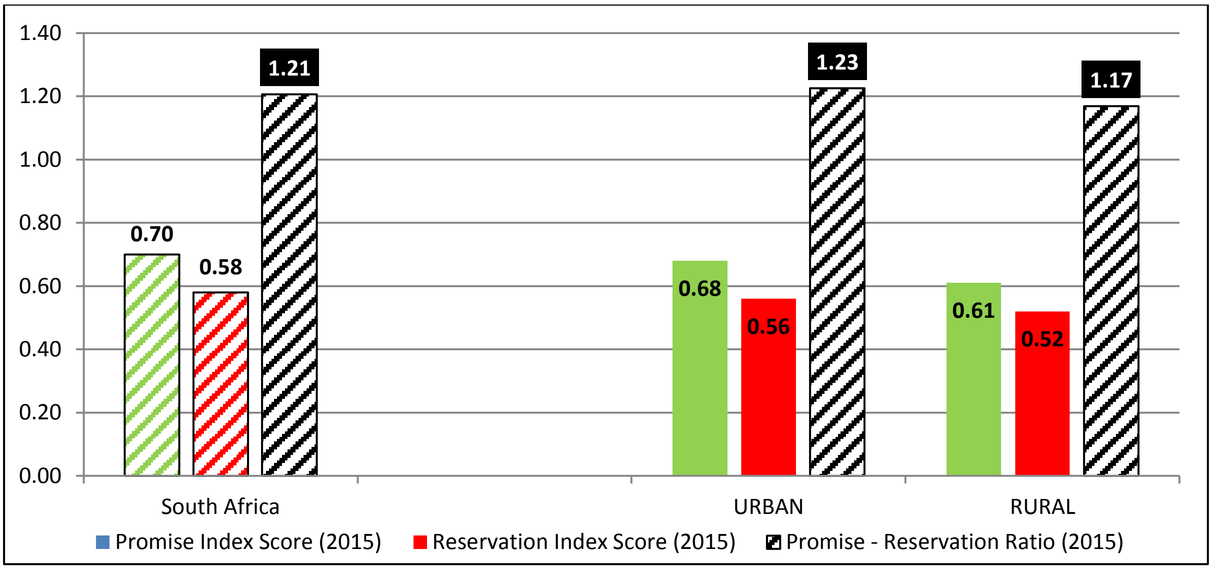


Chart 6.15: *Index of scientific promise and reservation* by rural / urban location group

The results of this analysis by rural / urban classifications may be indicative of related developmental disparities between rural and urban locations that may influence access to services, education, technology and related areas influencing overall attitude formation. Furthermore, South Africa's

[115] Response category text: *Neither Agree Or Disagree*

rural population is predominantly made up of members of the black race group (84.8% in this sample), which related to the aforementioned developmental context and the lower result within the race group analysis may further be influencing this output.

The above discussion on the index of scientific promise and reservation has drawn attention to the existence of greater overall attitudes of scientific promise within both rural and urban sub-samples. Data outputs from the measure of attitudinal ambivalence confirms that among urban respondents a greater proportion of participants achieved a net-positive attitudinal score (43.8%) compared to rural respondents (38.2%). This remains consistent with the above finding indicating a higher likelihood of urban respondents exhibiting more positive attitudes toward science compared to rural respondents, despite the overall general positive attitudes across both location groups. Within the rural sub-sample, 18.9% of respondents achieved a net- negative attitudinal score compared to 18.1% among the urban sub-sample.

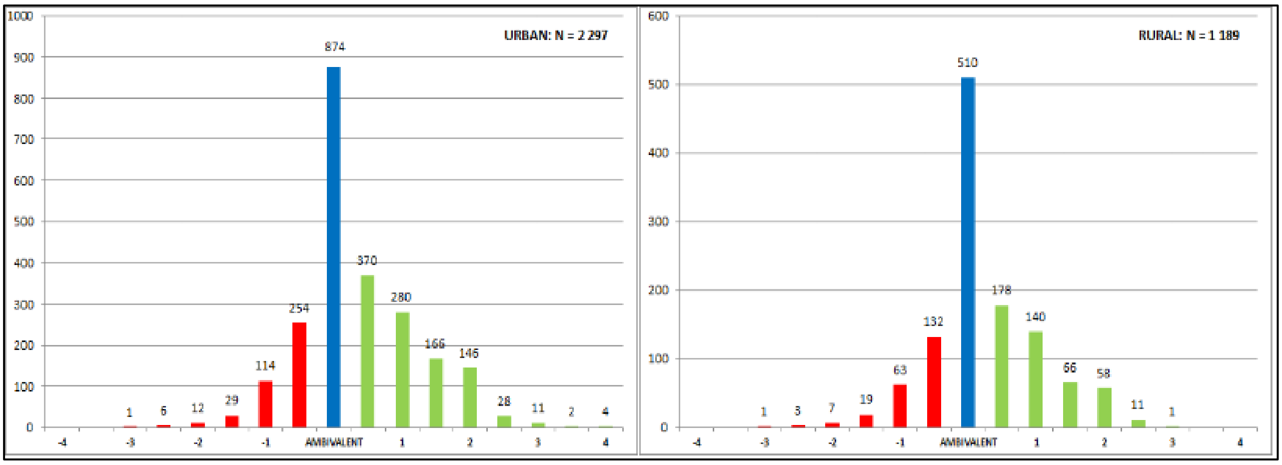


Chart 6.16: *Measure of Attitudinal Ambivalence* by location groups

Within the urban sample, 38.0% of respondents reported a degree of attitudinal ambivalence, compared to 42.9% of rural respondents. This proportion was lower than the overall national result on the measure of attitudinal ambivalence (39.7%) among the urban sub-sample, however was 3.2% higher than the national average among the rural sub-sample. As discussed under the results of the index of promise and reservation the factors explaining this variance may be many fold, however almost certainly these would be as a result of interactions between the geographic location and related demographic variables within the sample.

Conclusion

South Africans display an overall positive attitude toward science within the results presented in this chapter. In general 70.3% of South Africans agreed with *scientific promise* items, while there was a moderate level of agreement (58.1%) within the *scientific reservation* items. The general positive attitudinal position with regards to science is an encouraging output from within this research and highlights a strategic benefit toward science communication and the general public understanding of science in South Africa.

This positive view toward the *contribution of science to everyday life* among South Africans is shared across all race groups. While a generally higher positive agreement was attained within all groups, among the Indian / Asian sub-sample the proportion of agreement to *promise* and *reservation* items was lowest compared to their counterparts. Males and females did not differ significantly within their positive attitudinal response regarding science. Within location classifications, rural respondents appeared to hold less positive attitudes with regards to the contribution of science to daily life, compared to urban respondents. Participants with a higher level of educational attainment were significantly more positive, compared to respondents within the lower educational attainment categories. South Africans between the age of 20-39 and 50-59 years old displayed similarly strong positive scientific attitudes. Individuals younger than 20 and those older than 60 years displayed weaker positive attitudes within their response to these questionnaire items.

The *index of scientific promise and reservation* presents a ratio of scores attained within the scientific promise and those obtained within the scientific reservation items. The ratio obtained by the entire South African population was 1.21. This result is in confirms to the outcome of the attitudinal measurement items, wherein a larger agreement with the positive attitudinal items is presented in this chapter. Further to the above, this result compares favourably to previous studies conducted in South Africa producing this index, while demonstrating some variation to international counterparts. Within race groups, coloured respondents achieved the highest ratio for this index (1.34) while white respondents produced a result of 1.32. Both these race groups therefore achieved a higher index score than the national average and indicated stronger positive attitudes to science. Among Indian / Asian respondents (1.22) and black respondents (1.17), a lower ratio was achieved, indicating weaker positive attitudes in these demographic groups. Males demonstrated a slightly stronger positive attitude to science within this index (1.22) compared to females (1.20), however this was not found to be statistically significant. As per the expectation, urban respondents displayed generally stronger positive attitudes to science (1.23) compared to rural respondents (1.17). Similarly, respondents with increased educational attainment presented the strongest positive attitudes. Respondents in all age groups displayed positive attitudinal response, though there were variations in the strength of these positive attitudes across classifications.

Within these attitudinal responses there were high levels of agreement with both *scientific promise* and *scientific reservation* items. Simultaneous positive and negative positions lead to a degree of attitudinal ambivalence. Within the overall South African population, a larger share of respondents indicated a positive attitudinal position, however 39.7% of respondents (n=3 486) indicated an overall attitudinal ambivalence with regards to science. This is of concern as it may lead to increased malleability of attitudes to science, particularly within demographic segments with weaker positive *promise-reservation* ratios tending closer to 1.00. These results also reflected some degree of variability with respect to race group classification. White (32.4%) respondents reported the lowest degree of ambivalence compared to Indian / Asian (36.4%) and coloured (37.1%) respondents. The level of attitudinal ambivalence within the black race group was measured at 41.5%.

As a result of this race group accounting for the largest share of the national population, changes in attitudinal positions within this group due to this ambivalence would have significant impacts on the overall South African public understanding of science. Similarly, female respondents demonstrated a higher degree of attitudinal ambivalence (40.4%) compared to males. This result is further echoed within the location variable, wherein 38.0% of urban respondents report a degree of attitudinal ambivalence, while 42.9% of rural respondents reflect this attitudinal position. Within the educational attainment categories respondents with pre-matric education demonstrate a degree of ambivalence measured at 41.9%, while 37.8% report this position within the completed matric sub-sample. Interestingly, respondents with a post-matric education report a higher degree of attitudinal ambivalence, 1.9% higher than those with a completed matric, which does indicate a greater critical attitudinal position within this cohort. Younger respondents generally displayed a lower degree of attitudinal ambivalence compared to those in older age groups. Respondents older than 60 years demonstrated the highest degree of attitudinal ambivalence (45.8%). This highlights the important influence of age with respect to the legacy impacts of apartheid and the influence this may have on attitudes to science among older South Africans.

Chapter Seven

Descriptive Survey Results:

Interest in Science

Science is simply the word we use to describe the method of organizing our curiosity and interest in the world around us.

Tim Minchin (2013)

Introduction

Insight into the level of interest in areas of scientific advancement is a necessary precursor to the measurement of general public understanding and engagement activities. Interest in science would moderate information seeking behaviour, knowledge and ultimately participation in scientific discussions and engagement activities.

Based on this foundation, this research adopted *interest in science* as an important element of the overall South African public understanding of science.

OVERALL NATIONAL RESULTS FOR INTEREST IN SCIENCE ASSESSMENT ITEMS[116]

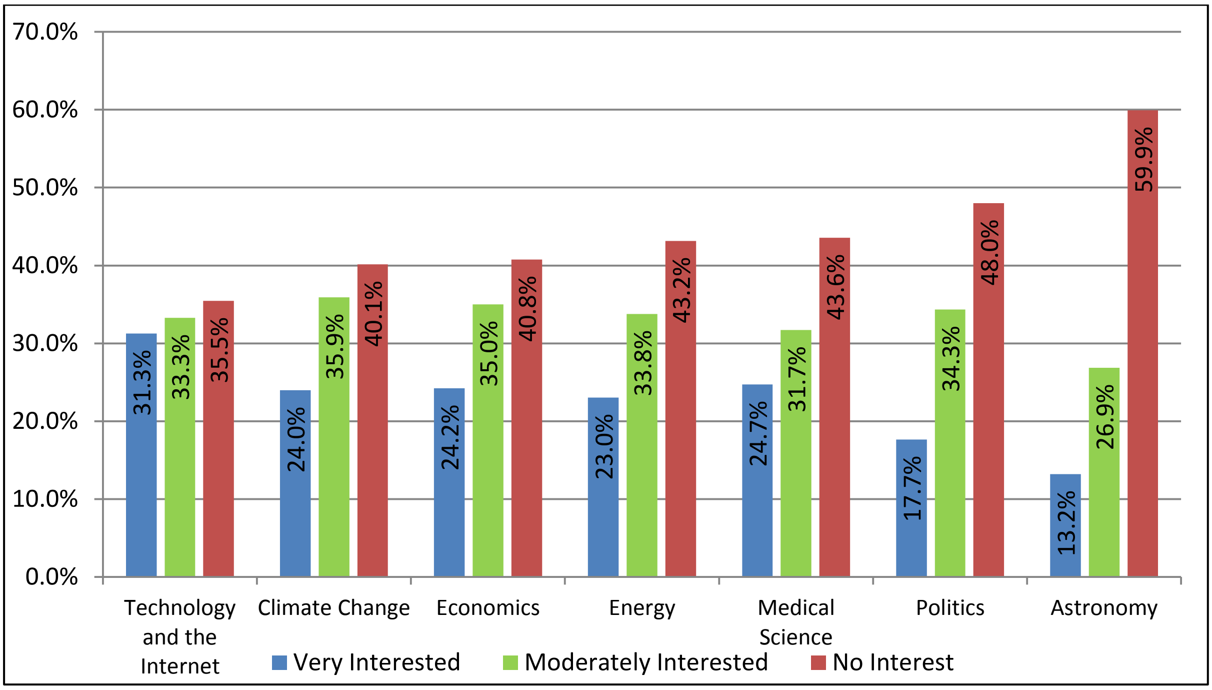


Chart 7.1: Overall result: South African *Interest in Science* assessment (valid %)

The response category attracting the highest proportion of valid response was consistently the *no interest* option (see chart 7.1). Overall response patterns at each item then reveal that respondents'

[116] The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

next most frequent selection was within the *moderately interested* category, and the lowest proportion of response was within the *very interested* option.

It remains important to note that among the three response categories, a two-level expression of *interest* is recorded within the *very interested* and *moderately interested* categories, while *no interest* is recorded within a single response option. Within this assessment of respondents' *interest in science*, it then became valuable to combine the response options for the *very interested* and *moderately interested* options into a single *SUM Interested* response reporting format. Wherever possible the *SUM Interested* responses will be disaggregated to ensure that the reporting is still able to convey a sense of the *interest intensity* within the original data.

Chart 7.2 presents the revised *SUM interest* reporting option. The category attracting the highest level of overall interest was *technology and the internet* (64.5% - 31.3%*[117]). This was followed by the interest areas for *climate change* (59.9% - 24.0%*); *economics* (59.2% - 24.2%*); *energy* (56.8% - 23.0*) and *medical science* (56.4% - 24.7%*).

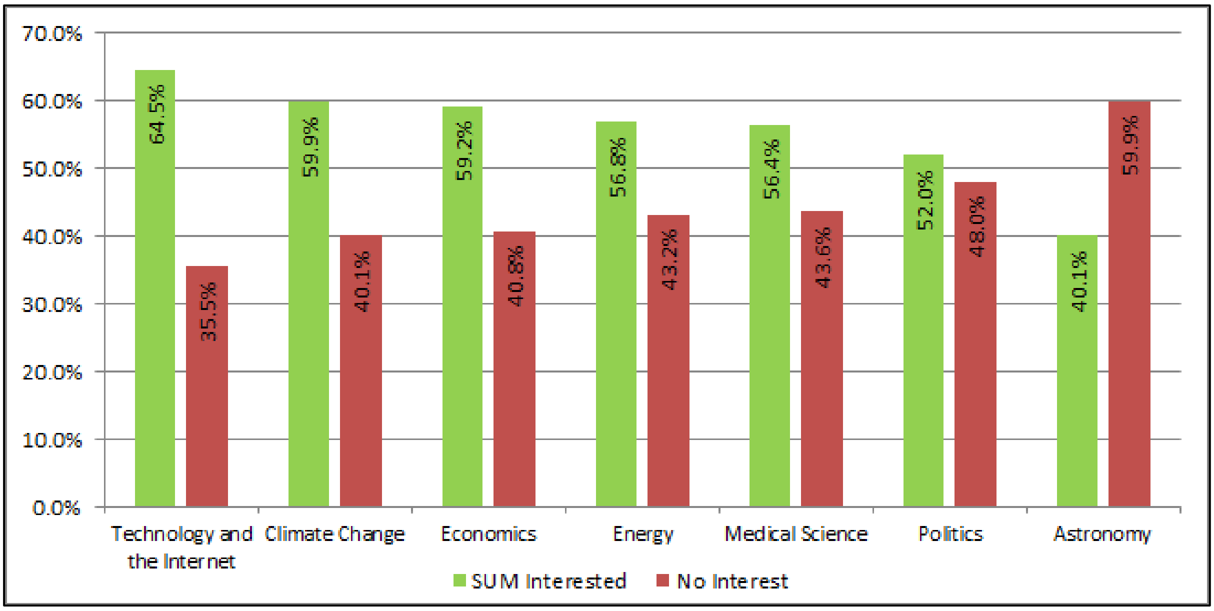


Chart 7.2: Overall result: South African *Interest in Science* assessment (combined interest categories)

The interest area for *astronomy* was the only item that attracted a higher proportion of *no interest* responses (59.9%). Data from within the *scientific knowledge* assessment, revealed a similar response pattern, where South Africans in general were less knowledgeable on aspects related to *astronomy* - with only 28.4% of respondents able to provide a scientifically correct response to the *astronomy* related item (see chapter five).

[117] * will denote the proportion within the reported *SUM interested* value that reported into the *very interested* response option

Response within the *very interested* response category for this survey was compared to response within the same category from the HSRC-SASAS (2013) data. The HSRC questionnaire for the 2013 iteration of the SASAS survey had 5 of the 7 items in common with the current research instrument[118]. The highest ranked interest item in the HSRC-SASAS (2013) data was the *medical sciences* (52.0%) followed by *climate change* (31.0%) then *technology and the internet* (28.0%). Items related to *economics* (15.0%) and *astronomy* (13.0%) attracted the lowest interest scores (see chart 7.3).

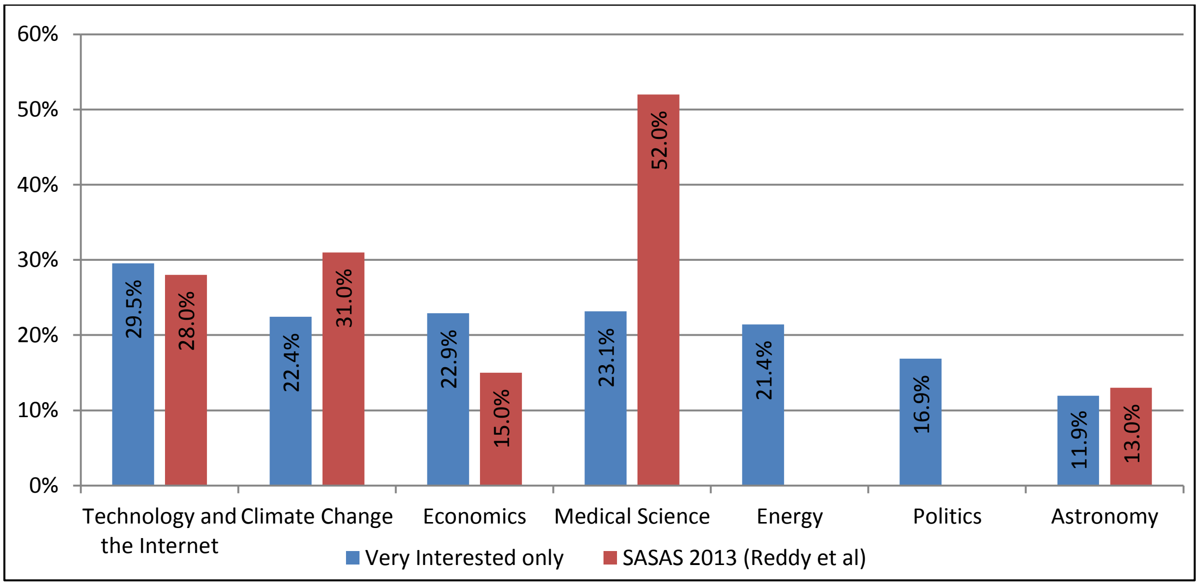


Chart 7.3: Interest in Science: Comparison to SASAS (2013) data (*very interested* responses only)

Comparing the HSRC-SASAS (2013) data and the data from within the current study, large variations were recorded with the *medical science* (Khayabus: -28.9%) as well as the *climate change* (Khayabus: -8.6%) interest areas. *Technology and the internet* recorded similar values to those reported in the 2013 SASAS study, while the area of *economics* demonstrated a 7.9% increase on the value reported in 2013. In both studies the area of *astronomy* achieved the lowest proportional expression of interest, with a marginally higher level recorded in 2013.

Result from the *interest in science* measure will be further explored by the various demographic classifications within the next part of this chapter.

The data will be presented thematically by the following classifications: *population group; gender; geographic location; educational attainment* and *age*.

There was a significant difference in the level of *interest in science* for respondents from different race groups (X^2=68.117, p < 0.001). White respondents demonstrated a higher likelihood of being

[118] Both this survey and the HSRC-SASAS survey included items for: *technology and the internet*; *climate change; economics; medical science and astronomy*. The SASAS 2013 questionnaire did not feature items for *energy* or *politics*

interested (*SUM interest*) in any of the 7 questionnaire items (60.0%); followed by black respondents (53.3%) and then Indian / Asian respondents (44.5%). Coloured respondents presented the lowest *SUM interest in science* proportion, with only 39.6% indicating a level of interest across the any of the 7 items.

Gender did not demonstrate a statistically significant influence for the overall population level of interest in science across the items (X^2=2.041, p > 0.05). The average proportion of female respondents expressing *SUM interest* across the 7 items was 49.6% compared to 54.6% recorded for male participants (n = 3 486). This remains consistent with research indicating greater male interest in science; however, within this study it was not found to be statistically significant at an aggregate level.

*Average across 7 interest areas	Very Interested	Moderately Interested	No Interest	D/K	N
NATIONAL	**21.2%**	**30.9%**	**41.5%**	**6.4%**	**3 486**
		-			
RACE	**N = 3 486**				
BLACK	22.3%	31.0%	39.1%	7.6%	**2 523**
WHITE	25.2%	34.8%	38.9%	1.1%	**408**
INDIAN / ASIAN	20.5%	24.0%	53.2%	2.3%	**121**
COLOURED	11.2%	28.4%	54.5%	5.9%	**434**
GENDER	**N = 3 486**				
FEMALE	20.0%	29.6%	43.4%	7.0%	**1 747**
MALE	22.4%	32.2%	39.6%	5.8%	**1 739**
GEOGRAPHIC LOCATION	**N = 3486**				
URBAN	23.2%	32.0%	40.0%	4.8%	**2 297**
RURAL	17.3%	28.8%	44.5%	9.4%	**1 189**
EDUCATION	**N = 3486**				
PRE-MATRIC	15.5%	27.5%	46.8%	10.2%	**1 369**
MATRIC COMPLETED	22.8%	32.7%	40.2%	4.3%	**1 578**
POST-MATRIC	30.7%	34.2%	31.9%	3.2%	**539**
AGE	**N = 3 472**				
<20 YEARS	26.6%	28.6%	38.2%	6.6%	**170**
20-29 YEARS	23.7%	31.4%	39.8%	5.0%	**1 101**
30-39 YEARS	20.8%	32.2%	40.4%	6.5%	**956**
40-49 YEARS	18.8%	32.1%	43.0%	6.1%	**598**
50-59 YEARS	19.4%	30.1%	42.2%	8.2%	**372**
60+ YEARS	15.2%	25.0%	50.2%	9.7%	**275**

Table 7.4: Results of *Interest in Science* by demographic classifications in Khayabus wave 2, 2015

The association of *geographic location* with *interest in science* was assessed by each of the 9 South African provinces as well as by the rural / urban classification. Both location classification categories were found to be significantly associated with the measure of *interest in science* (Province: X^2=214.270, p < 0.001; Rural / Urban: X^2=18.334, p < 0.001). Within the rural / urban classification significantly more urban respondents (55.2%) reported interest across the question set, compared to rural respondents (46.1%). Provincial location revealed that the province reporting the highest *(SUM) interest* in science across the 7-items was Gauteng (61.6%); Mpumalanga (58.9%) followed by KwaZulu Natal (52.1%) and the Limpopo province (51.3%). The remaining five provincial areas achieved a *SUM interest* result below 50%.

Educational attainment was found to be a highly significant factor on overall interest in science (X^2=65.349, p < 0.001). Respondents with *pre-matric educational attainment* demonstrated a significantly lower reported level of *(SUM) interest* in science (43.0%) compared to respondents with post-matric education (64.9%).

At the national aggregate level, respondent age classifications did not demonstrate a statistically significant association with *interest in science* measures (X^2=15.904, p > 0.05). Respondents younger than 50 years generally reported higher interest in science, while those older than 50 years report interest levels below 50%. Those older than 60 years reported the lowest interest in science (40.2%) among all age classifications.

<u>EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH INTEREST IN SCIENCE</u>

CHAID analysis was employed to ascertain the relationships between the various demographic variables discussed above. The demographic variables included within the analysis included gender; race; household income; educational attainment; geographic location (rural-urban); employment and age. The CHAID outputs will be valuable in understanding the relationships between the variables listed as well as how they best combine to explain respondent *interest in science*.

The output of the CHAID analysis is presented graphically in figure 7.1 below. Results indicate that the variables best predicting respondent interest in science are *educational attainment; race* and *geographic location*. Respondents with a post-matric education record the highest interest in science, 12% percentage points higher than the sample average (All: 32.4%). Respondents self-reporting into the black, white and Indian / Asian sub-samples, having completed matric, similarly report higher levels of interest in science.

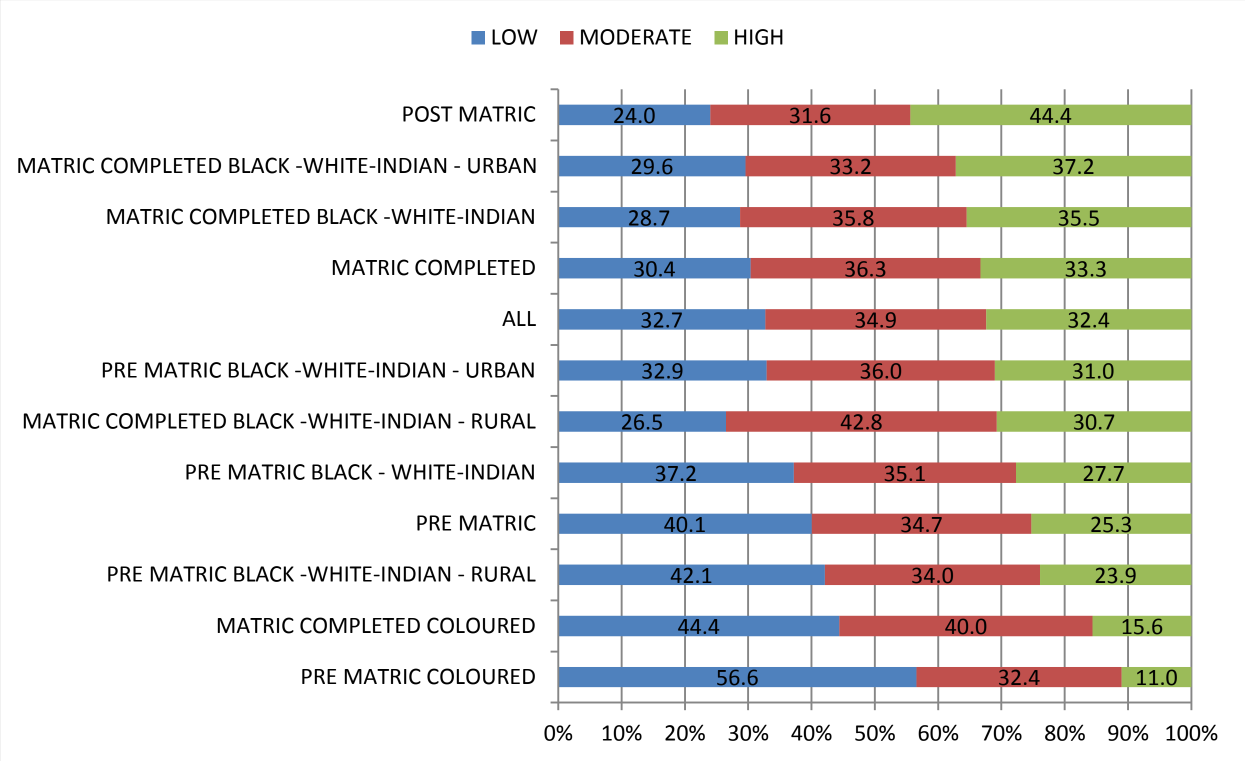


Figure 7.1: Output of CHAID analysis: Interest in Science

Respondents in urban areas report greater interest in science, compared to their rural counterparts. The combination of having a completed matric education, being black, white or Indian / Asian and residing within an urban area appear to be the strongest predictors of interest in science. Respondents with lower educational attainment and living within rural areas report lower interest in science. Coloured respondents report the lowest interest in science. These three predictors, along with additional variables of significance will be included in the *multinomial logistic regression* modelling toward the output of a predictive model of interest in science measures in South Africa.

The influence of these demographic variables will be explored in greater detail within the next sections, each devoted to one of the variables discussed above.

INTEREST IN SCIENCE BY RACE

The overall national result for *interest in science* by race yielded a statistically significant association between these variables (X^2=68.117, $p < 0.001$). White respondents reported a higher interest in science (60.0% - *25.2%[119]) compared to other race groups. Black respondents reported the second highest interest in science (53.3%) wherein 22.3% indicated that they were *very interested* across the 7-items in the question set. Indian / Asian respondents reported lower interest in science (44.5% - * 20.5%), while coloured respondents reported the lowest overall interest across all questionnaire items (39.6% - *11.2%).

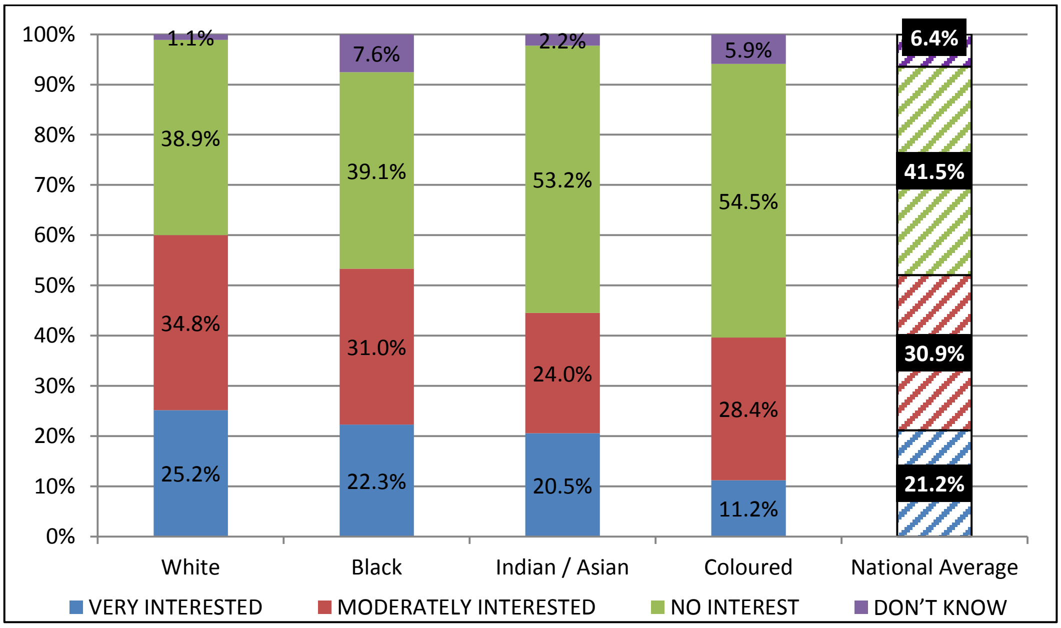


Chart 7.5: Average response by population group: *Interest in Science* assessment

Black and white respondents reported proportionally similar values within the *no interest* response category while Indian / Asian and coloured respondents demonstrated similar response patterns. White (1.1) and Indian / Asian (2.2%) participants reported the lowest overall response within the *don't know* option while coloured (5.9%) and black (7.6%) respondents selected this option significantly more frequently.

Within race classifications there were variations in the ranking of the 7 scientific-interest areas. White respondents report the highest interest proportion within the *technology and the internet* (71.3%) item; followed by *climate change* (66.9%); *economics* (65.9%); *energy* (62.0%) and issues related to *medical science* (61.3%). Respondents within this demographic classification did not demonstrate high interest in *politics* (47.5%) while similarly reporting the lowest level of interest

[119] As above, * will denote the proportion within the reported *SUM interested* value that reported into the *Very Interested* response option

toward *astronomy* (45.1%). The items *politics* and *astronomy* further received the highest level of *no interest* responses within the white sub-sample (see chart 7.6).

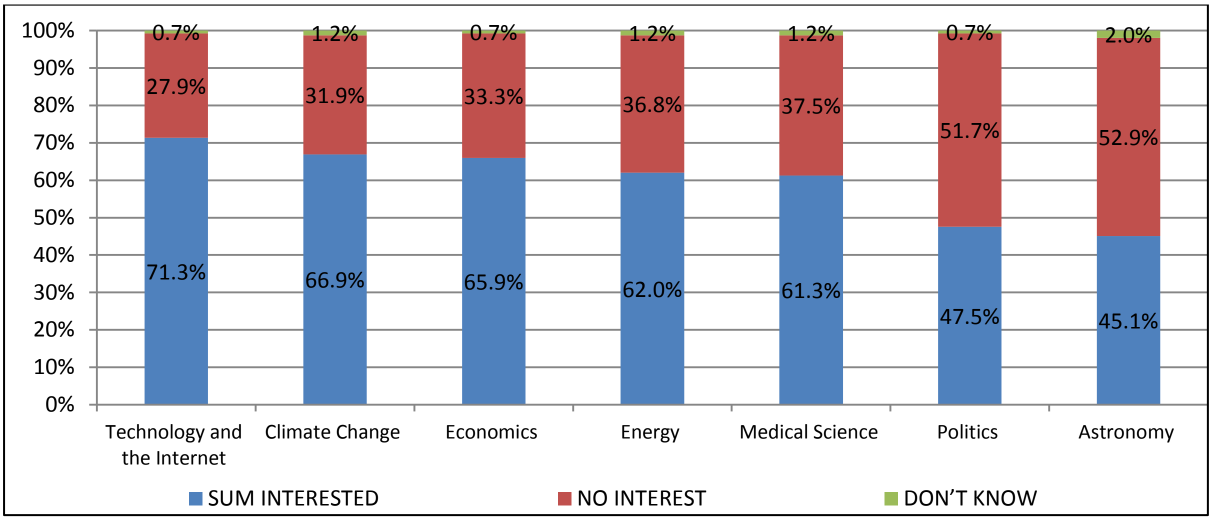


Chart 7.6: Average response by white subsample: *Interest in Science* assessment

Black respondents reported the highest interest within the *technology and the internet* (61.7%) item; followed by *economics* (57.5%); *climate change* (56.2%) and *energy* (54.0%). *Politics* (53.3%), among this sub-sample was ranked equally high to *medical science* (53.3%), while astronomy was the lowest ranked interest area (37.1%). The proportion of black respondents selecting the *don't know* response option was significantly higher than in other race groups (overall – 7.6%). The items receiving the highest proportion of *don't know* response within this sub-sample were *astronomy* (11.7%); *energy* (8.3%); *climate change* (7.5%) and *medical science* (7.5%). As within the white sub-sample, the item for *astronomy* attracted a higher proportion of *no interest* responses (51.1%) compared to the remaining 6 items within this question set (see chart 7.7).

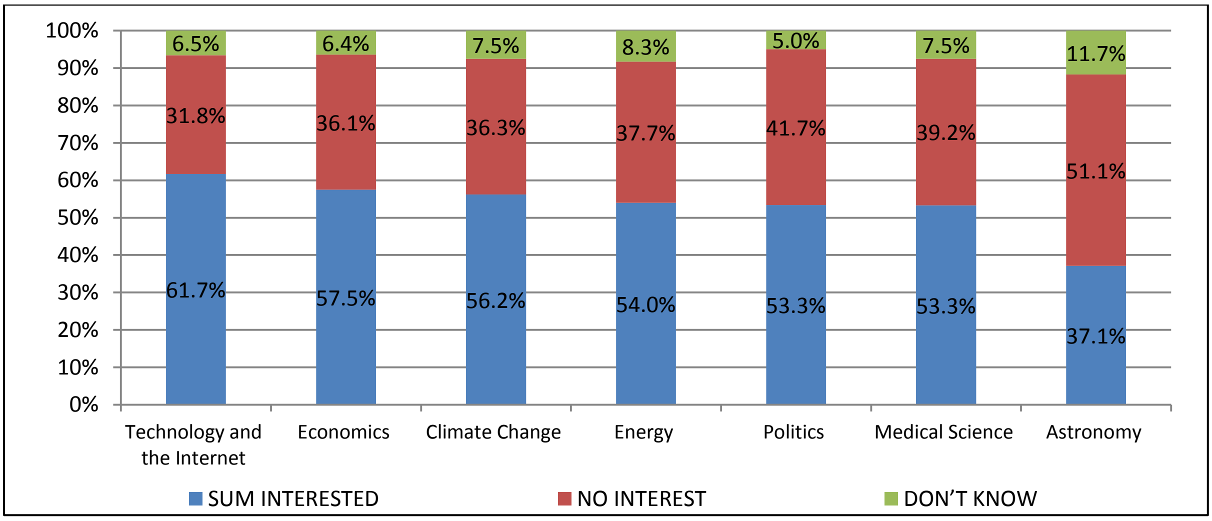


Chart 7.7: Average response by black subsample: Interest in Science assessment

Reported interest in science among the Indian / Asian sub-sample is reflected in chart 7.8 below. *Technology and the internet* (52.9%) received largest proportion of *SUM interest* selections, as with the black and white population groups. This sub-sample then ranked *medical science* (52.1%) followed by *economics* (49.6%); *climate change* (47.9%) and *energy* (42.1%) as the next highest interest areas. The Indian / Asian cohort did not report *astronomy* (36.4%) as the lowest ranked interest area, but instead *politics* received the lowest level of proportional *SUM interest* selections (30.6%). A significantly larger proportion of Indian / Asian respondents indicated *no interest* in *politics* (67.8%).

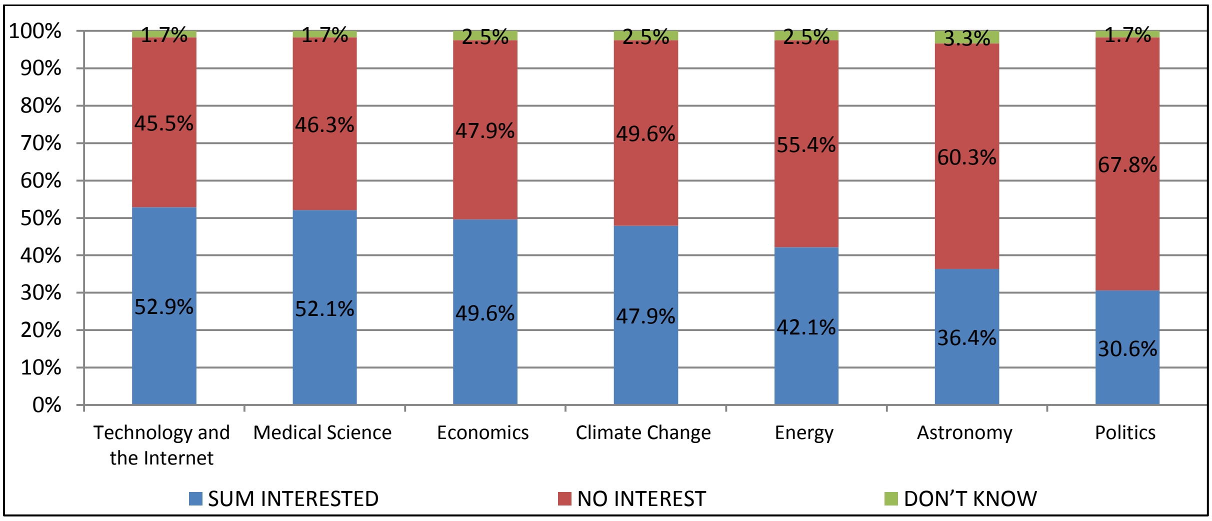


Chart 7.8: Average response by Indian / Asian subsample: Interest in Science assessment

The race group attracting the lowest overall level of interest across all seven questionnaire items was within the coloured sub-sample (39.6%).

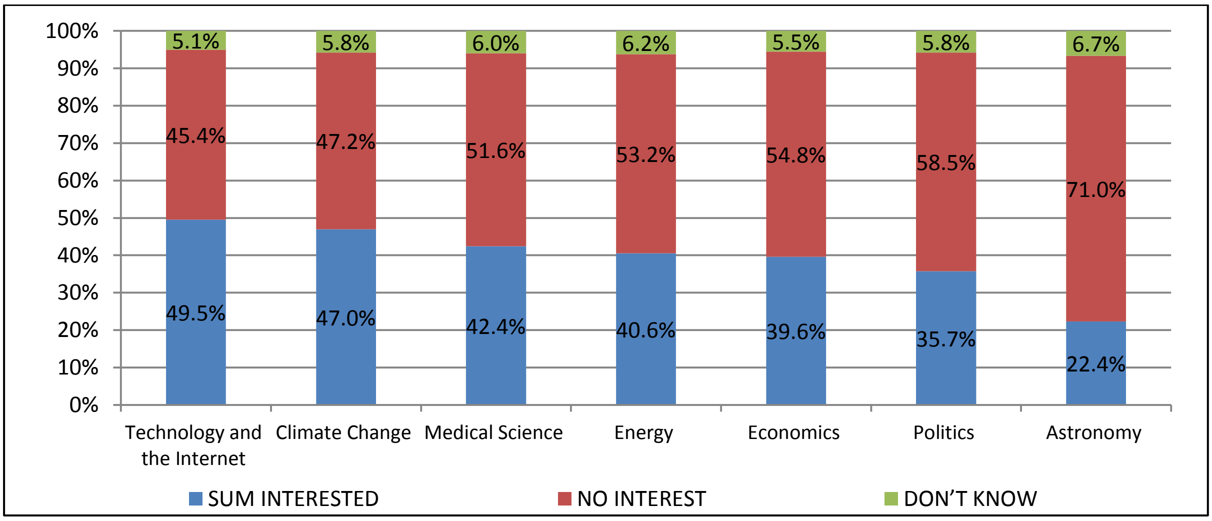


Chart 7.9: Average response by coloured subsample: Interest in Science assessment

The highest ranked area of scientific interest within this cohort was within the *technology and the internet* (49.5%) item; followed by *climate change* (47.0%); *medical science* (42.4%) and *energy*

(40.6%). Interest among the coloured sub-sample for *economics* and *politics* were both below 40% (see chart 7.9). The lowest overall *SUM interest* for any of the questionnaire items, across all population groups was measured for coloured respondents within the *astronomy* item (22.4%). Response within the *don't know* option were highest for the items *astronomy* (6.7%); *Energy* (6.2%) and *medical science* (6.0%).

INTEREST IN SCIENCE BY EDUCATIONAL ATTAINMENT

The level of respondent *educational attainment* has been shown to demonstrate a statistically significant association with level of *interest in science* (X^2=65.349, p < 0.001). Respondents with higher levels of educational attainment report increased levels of interest across all 7 areas of science within the question set.

Respondents with pre-matric educational attainment report lower overall interest in science (43.0% - *15.5%) compared to respondents with a completed matric (55.5% - *22.8%) and those with post-matric education (64.9% - *30.7%).

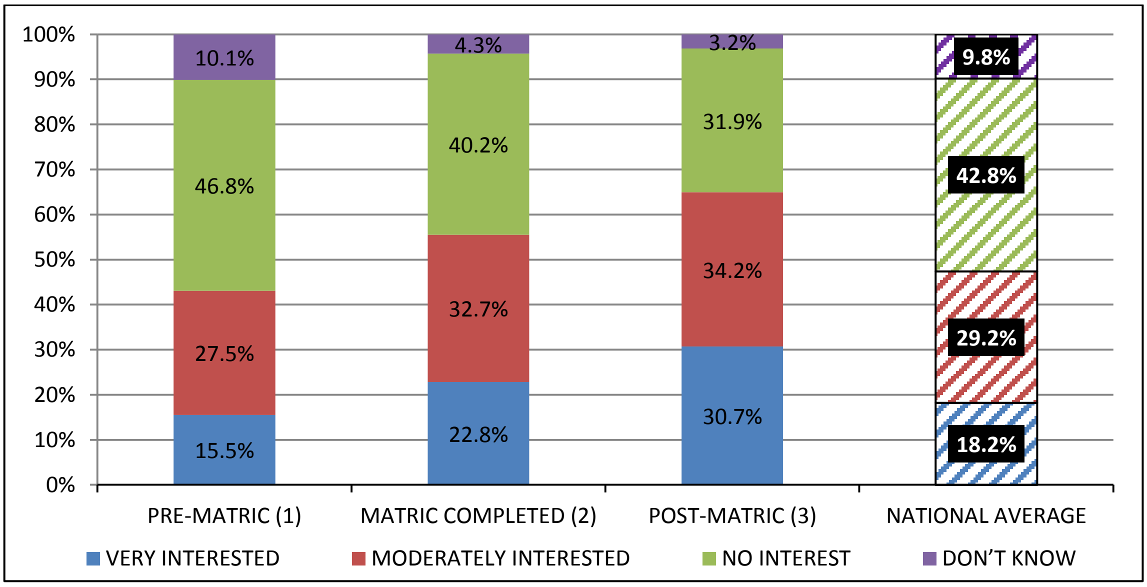


Chart 7.16: Average response by educational attainment group: *Interest in Science* assessment

Similarly, responses within the *no interest* option declines as respondent education level increases (see chart 7.16). Significantly, respondents within the pre-matric educational attainment category responded below the level of the national average for *SUM interested* responses, while yielding significantly higher frequencies of response within the *no interest* and *don't know* response options.

Respondents with pre-matric educational attainment did not differ considerably in the overall ranking of scientific interest areas. As discussed above, respondents within this group did demonstrate statistically significant lower levels of interest compared to other groups. The most frequently selected interest area remains *technology and the internet* (48.3%); followed by *climate change* (47.8%); *economics* (45.4%); *medical science* (44.1%) and *energy* (43.9%). Respondents within the pre-matric group selected *politics* (43.7%) and *astronomy* (28.2%) least frequently as areas of scientific interest. Within all of the *interest in science* items, respondent reported levels of *no interest* was above 40.0%; ranging from 41.9% for *climate change* to 58.4% for the interest area of *astronomy*. The pre-matric sub-sample were significantly more inclined to make use of the *don't know* response option, with an average response in this category being 10.2% - however this did range between 7.5% for *politics* and 13.4% for *astronomy* (see chart 7.17).

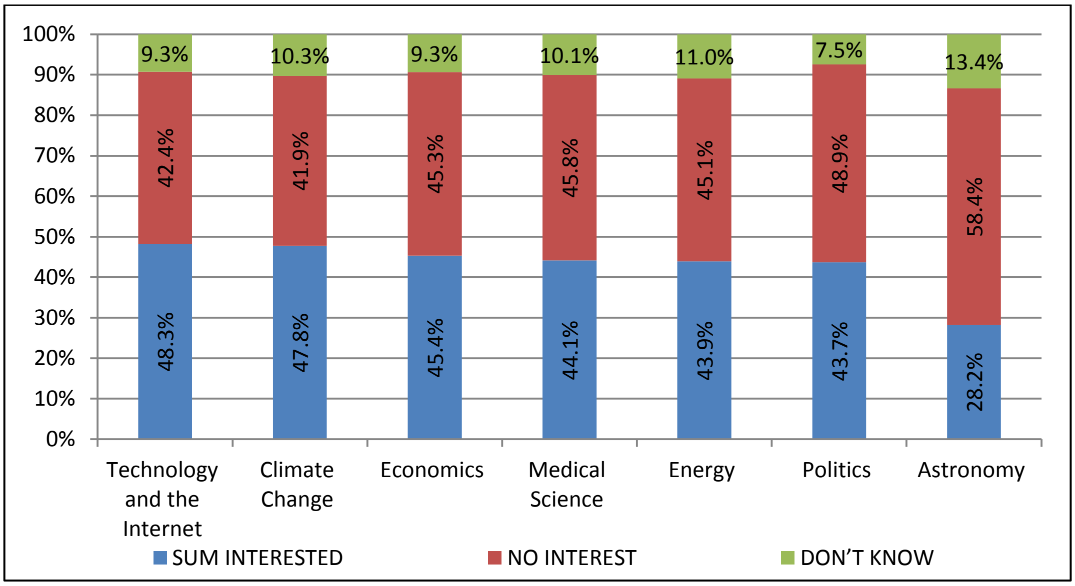


Chart 7.17: Average response by pre-matric educational attainment subsample: *Interest in Science* assessment

Within the sub-sample of respondents reporting a completed matric educational attainment level, the pattern of response was relatively similar to those within the pre-matric group. Respondents most frequently reported *technology and the internet* (67.1%) as the area of greatest interest, followed by *economics* (59.9%); *climate change* (58.8%); *medical science* (56.2%) and *energy* (55.8%).

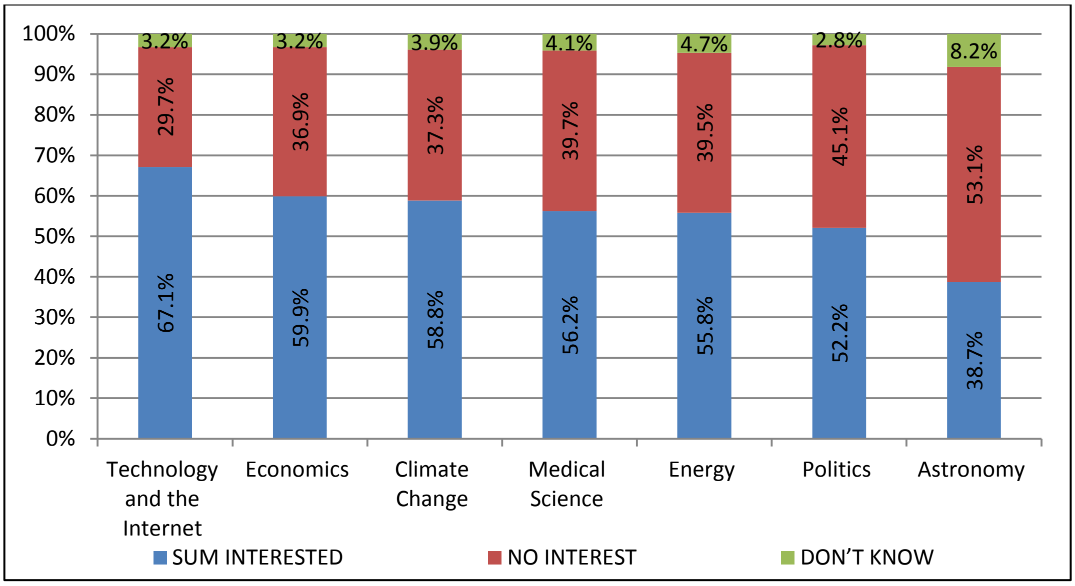


Chart 7.18: Average response by matric completed educational attainment subsample: *Interest in Science* assessment

This sub-sample similarly reported being least interested in areas of *politics* (52.2%) and *astronomy* (38.7%). Across all interest areas, the completed matric sub-sample reported significantly higher levels of interest across all 7 areas of science, when compared to those within the pre-matric educational attainment group. While response within the *no interest* option was less frequent, this option was more frequently selected for the items dealing with *politics* (45.1%) and *astronomy* (53.1%). Respondents within the matric completed classification selected the *don't know* response option 2.3 times less frequently, compared to the pre-matric sub-sample. However respondents within this cohort still included *don't know* selections within their response (see chart 7.18 - *Astronomy* – 8.2%).

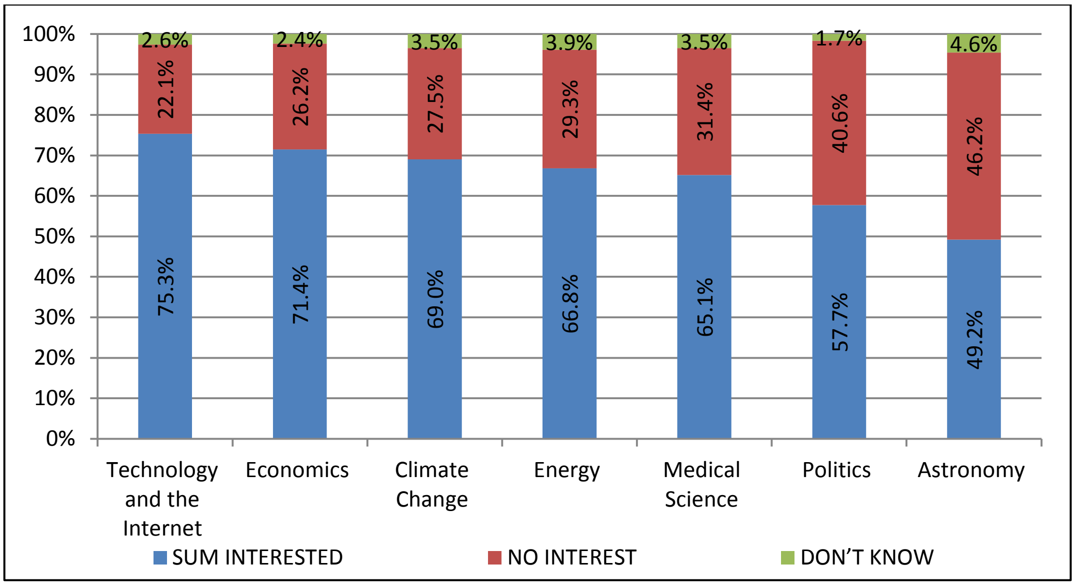


Chart 7.19: Average response by post-matric educational attainment subsample: *Interest in Science* assessment

Respondents with a post matric education accounted for 15.5% of the total survey sample (n = 3 486). Within this classification, the most frequently selected interest area was *technology and the internet* (75.3%); followed by *economics* (71.4%); *climate change* (69.0%); *Energy* (66.8%) and *medical science* (65.1%).

Similar to the other educational attainment groups, *politics* (57.7%) and *astronomy* (49.2%) were the categories of least interest for respondents with post-matric education. All *SUM agreement* responses within this category were significantly higher than responses recorded within the matric completed and the pre-matric groups. Response patterns within the *no interest* option reflect lower proportions, ranging from 22.1% (*technology and the internet*) to 46.2% (*astronomy*). Respondents with a post matric education selected the *don't know* response 3.2 times less frequently compared to those with pre-matric education and 1.3 times less frequently compared to respondents with a completed matric education.

Conclusion

Within the survey results, 55.6% of respondents declared a higher level of interest across the 7 scientific areas. This included 22.6% that indicated they were *very interested* while 33.0% provided a *moderately interested* response. Overall 44.4% of the sample declared no interest across all questionnaire items. This average level of interest among South Africans is a very positive outcome as it indicates a greater curiosity about scientific areas within the general population. A greater level of interest was declared for areas related to *technology and the internet* followed by *climate change* and *economics.* Across the sample the areas attracting the lowest level of reported interest were *politics* and *astronomy.*

Across all race classifications, white respondents reported the highest level of interest. This group was following by black; Indian / Asian and then coloured respondents. White and black respondents generally demonstrated interest levels above that of the national average while coloured and Indian / Asian respondents generally expressed interest levels below that of the national average. All race groups expressed interest in areas related to *technology and the internet* and *climate change*. Among white and black respondents this also included *economics*, while within coloured and Indian / Asian groups the top interest areas included *medical science.* While it is clear that the patterns of interest in science do vary within race classifications, the general selection of interest areas remains relatively similar across groups. However it remains important to note that the proportionality of interest response did demonstrate significant variability.

Males expressed a generally greater proportional interest in scientific areas compared to females in this study. Areas presenting a statistically significant variation in patterns of response by gender groups include: clim*ate change; technology and the internet; politics; economics* and areas related to *energy*. Interest areas between gender classifications did not deviate from the above mentioned overall result; however there were variations in the response proportions for interest in each area.

A larger proportion of urban respondents declared interest across the 7 items, compared to rural respondents. Both rural and urban respondents were most interested in areas of clim*ate change; technology and the internet* and *economics*; however in significantly different proportions. Rural respondents were more likely to indicate *no interest*, when compared to the urban sub-sample. Rural respondents, however, reported a greater interest in *politics* compared to urban respondents.

A statistically significant association was found between educational attainment level and interest in science. Respondents with higher educational attainment declared higher interest across all interest in science measurement areas. Respondents with post-matric education were less likely to select the *no interest* option compared to those with less educational attainment. Reported interest was highest within the *technology and the internet*; clim*ate change* and *economics* areas where respondents with pre-matric education would generally demonstrate lower levels of interest.

Respondents' age group classification did not show any significant association with the interest in science variable. Despite this, younger respondent's showed greater interest across all 7 areas of science compared to older respondents. This would likely be due to younger participants still being engaged in personal or family educational activities or employment requiring increased exposure to the questionnaire item categories. Respondents older than 60 years reported the lowest level of interest across all areas of science and were more likely to select the *don't know* response option compared to the younger age classifications.

Chapter Eight

Descriptive Survey Results:

Informedness in Science

Information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all.

Arthur C. Clarke (1993)

Introduction

The overall level of *informedness*, with respect to science would be highly related to the overall level of *interest* in science. As noted within the previous section, awareness of the general level of *interest in science* would be a necessary requirement toward developing a robust assessment of the South African public understanding of science. Similarly so, the development of an assessment of the general level of *informedness* about science would complement the established understanding of overall interest in science. This assessment would contribute immensely to an understanding of the interrelatedness of general *interest*, information seeking outcomes and measured levels of scientific knowledge among the South African population.

OVERALL NATIONAL RESULTS FOR INFORMEDNESS IN SCIENCE ASSESSMENT ITEMS[120]

The response patterns within the *informedness* items reflect that of the results presented within the *interest* in science items.

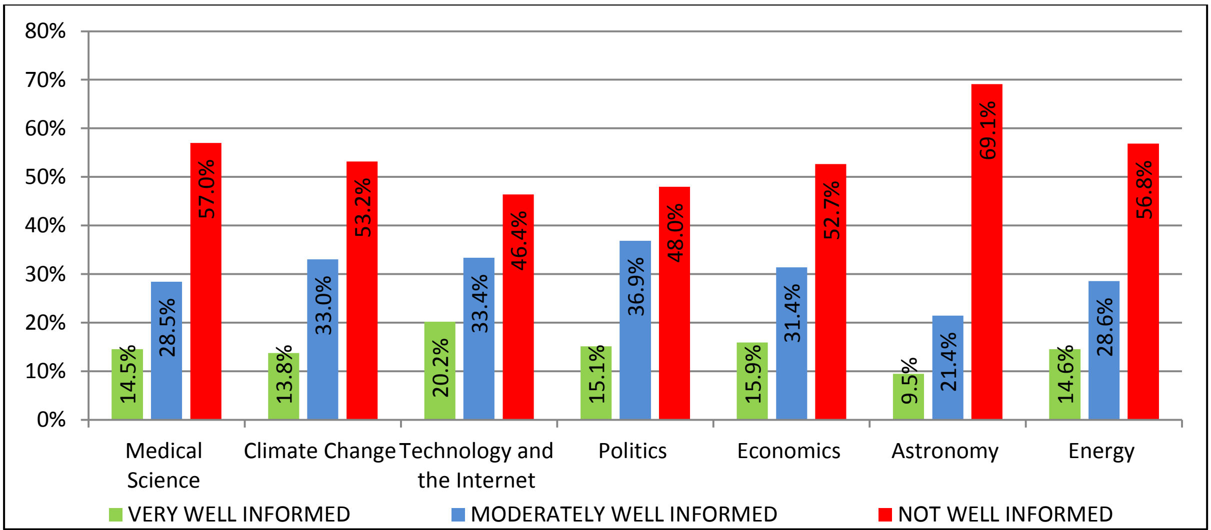


Chart 8.1: Overall result: South African *informedness in science* assessment (valid %)

[120] The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

The largest proportion of response achieved was within the *not well informed* option; which was followed by *moderately well informed* and the smallest proportion of response was within the *very well informed* selection.

Informedness in science response categories for *very well informed* and *moderately well informed* will be collapsed into a single *SUM informed* category for ease of data presentation. However where appropriate, the proportion of respondents within the *SUM informed* category reporting a *very well informed* response will be highlighted.

The data in chart 8.1 is presented again in chart 8.2, however within the revised *SUM informedness* format. It is apparent that the overall level of *informedness* among South Africans is lower than the earlier reported level of *interest* across the 7 scientific areas. Within 5 of the 7 items, the proportion of South Africans reporting *informedness* is lower than those that report being *not well informed*. Within the categories for *technology and the internet* (53.6% - *20.2%) and *politics* (52.0% - *15.1%) a larger proportion of respondents indicated a *SUM informedness* compared to the remaining 5 items in the question set. Within the informedness areas of *medical science* (57%); *energy* (56.8%) and *astronomy* (69.1%) a larger proportion of respondents indicated being *not well informed* compared to those reporting any level of informedness.

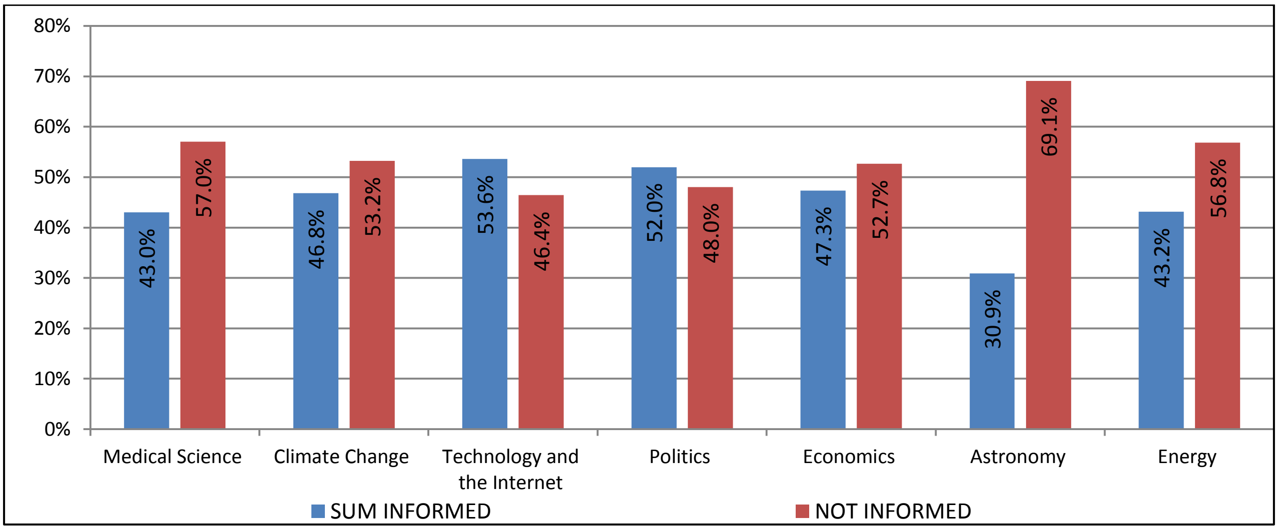


Chart 8.2: Overall result: South African *informedness in science* assessment (combined informedness categories)

The response proportions within the informedness area of *astronomy* correlates to the lower proportions of respondents that earlier indicated a low *interest* within this subject area. Within chart

8.3 it is apparent that there is a higher level of interest among South Africans, than there is a self-reported level of informedness, for these questionnaire items[121].

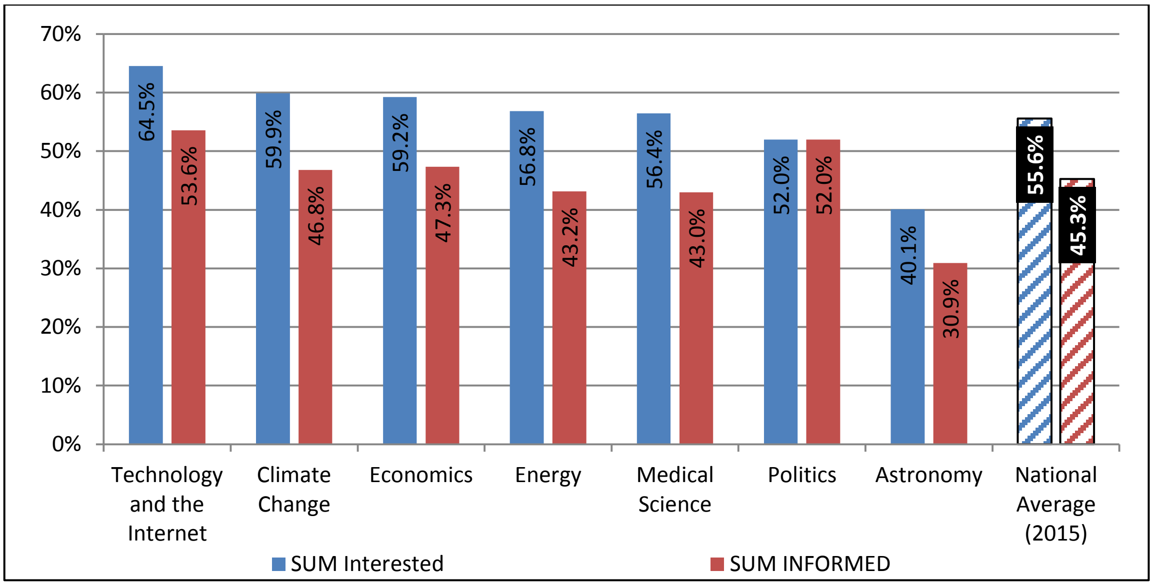


Chart 8.3: Sum Interested vs Sum Informed responses (Khayabus 2015, Wave 2)

Result for the *informedness in science* measure will be further explored by the various demographic classifications within the next part of this chapter. The data will be presented within the following classifications: *race group; gender; geographic location; educational attainment* and *age*.

A significant association was identified between race group classification and respondents reported level of informedness (X^2=78.068, p < 0.001). White respondents report of being more informed (54.7%) across the 7 scientific areas (*SUM informed*) compared to black (41.9%); Indian / Asian (35.4%) and coloured (32.0%) respondents.

Within the *informedness about science* items, gender classifications did not demonstrate a statistically significant association with level of informedness (X^2=5.336, p > 0.05). Proportionally, fewer females (39.8%) reported *SUM informedness* across the questionnaire items compared to the male sub-sample (44.1%). This is consistent with the result for the *interest* items and further is in agreement with the literature. Despite this, in the present data set, the association between gender and scientific informedness was not found to be statistically significant.

[121] Here the exception is within the Politics category, where there appears to be relative parity between Interest and Informedness levels.

	VERY WELL INFORMED	MODERATELY WELL INFORMED	NOT WELL INFORMED	D/K	N
NATIONAL	**13.7%**	**28.2%**	**50.5%**	**7.6%**	**3 486**
RACE	**N = 3 486**				
BLACK	14.1%	27.8%	49.3%	8.8%	**2 523**
WHITE	19.9%	34.8%	41.9%	3.4%	**408**
INDIAN / ASIAN	12.0%	23.4%	62.1%	2.5%	**121**
COLOURED	6.1%	25.9%	62.1%	5.9%	**434**
GENDER	**N = 3 486**				
FEMALE	13.2%	26.6%	52.1%	8.1%	**1 747**
MALE	14.3%	29.8%	48.9%	7.0%	**1 739**
GEOGRAPHIC LOCATION	**N = 3486**				
URBAN	15.5%	30.6%	47.9%	5.9%	**2 297**
RURAL	10.2%	23.5%	55.5%	10.9%	**1 189**
EDUCATION	**N = 3486**				
PRE-MATRIC	8.7%	22.7%	57.4%	11.2%	**1 369**
MATRIC COMPLETED	14.7%	30.4%	49.9%	5.0%	**1 578**
POST-MATRIC	23.4%	35.7%	35.0%	5.9%	**539**
AGE	**N = 3 472**				
<20 YEARS	14.8%	28.3%	50.2%	6.7%	**170**
20-29 YEARS	15.0%	28.1%	51.1%	5.8%	**1 101**
30-39 YEARS	13.2%	29.3%	49.3%	8.2%	**956**
40-49 YEARS	13.3%	30.4%	49.1%	7.2%	**598**
50-59 YEARS	14.4%	27.0%	48.9%	9.7%	**372**
60+ YEARS	9.1%	21.1%	58.4%	11.4%	**275**

Table 8.1: Results of *Informedness in Science* questionnaire items by demographic classifications

Within provincial boundaries as well as rural / urban location categories, a significant association was found with the level of respondent-reported scientific informedness (Provincial: X^2=304.679, p < 0.001; Rural / Urban: X^2=77.312, p < 0.001). At the provincial level, the highest proportion of respondents reporting *SUM informedness* was within the Gauteng province (55.4%) followed by Mpumalanga (49.2%) and the North West (47.3%). The provincial areas reporting the lowest proportion of *SUM informedness* was the Eastern Cape (34.5%) and the Northern Cape (27.0%). Within rural / urban classifications, rural respondents reported a lower proportion of *SUM informed* response (33.7%) compared to respondents within the urban sub-sample (46.1%).

The role of educational attainment level was again noted have a statistically significant association with reported levels of informedness (X^2=180.875, p < 0.001). Respondents with higher educational attainment levels report being significantly more informed compared to respondents within the lower educational attainment categories. Those with post-matric educational attainment report a *SUM informedness* proportion of 59.1%, compared to those with pre-matric education (31.4%).

Within the *informedness* items, respondent age classification was found to be statistically significant in relation to the reported level of informedness (X^2=26.954, p < 0.01). Across all age group classification a general decrease in the reported *SUM informed* response is observed wherein respondents younger than 20 years report among the highest[122] level of informedness (43.1%) while those older than 60 years report the lowest level of informedness (30.2%).

EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH INFORMEDNESS ABOUT SCIENCE

As in the preceding chapters, CHAID was employed in further understanding the relationships between the demographic variables contributing to respondent reported informedness about science. The variables included within the analysis included gender; race; household income; educational attainment; geographic location (rural-urban); employment and age.

Figure 8.1 below presents a graphical output of the CHAID analysis, and is discussed below.

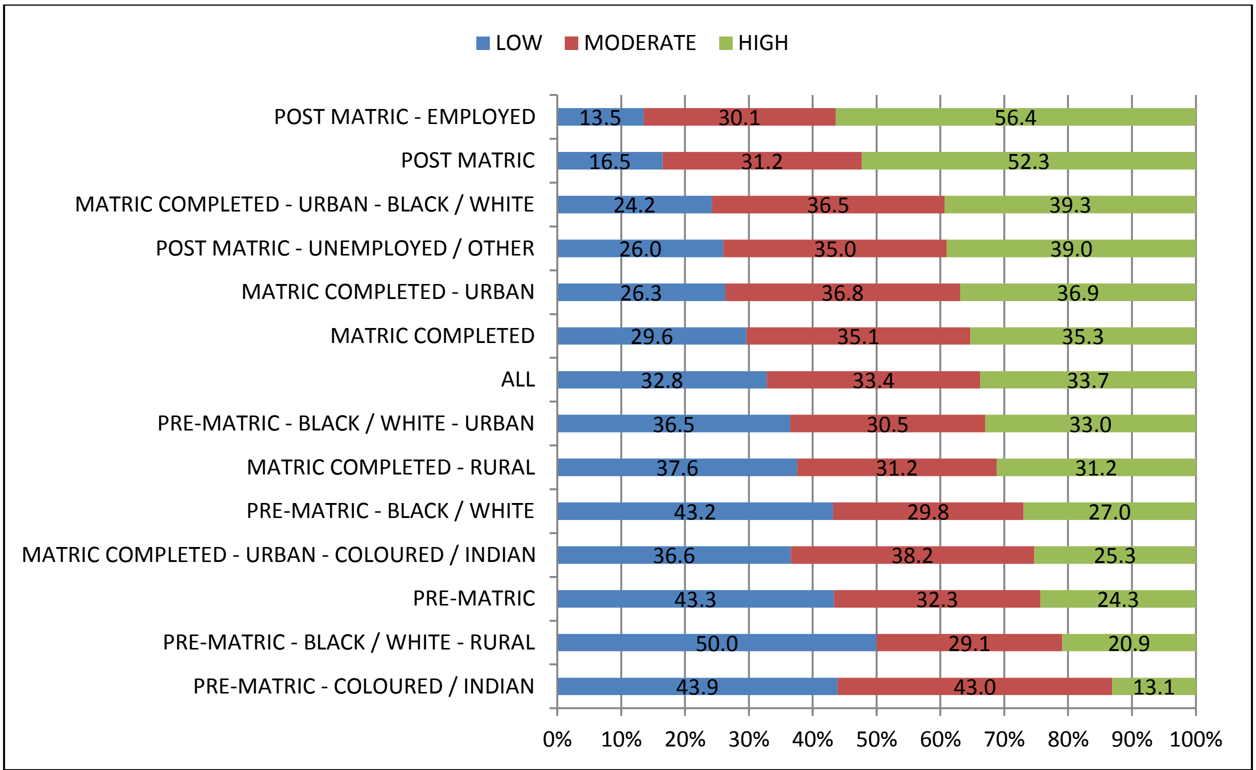


Figure 8.1: Output of CHAID analysis: Informedness about Science

Results from this statistical procedure indicates that four variables best explain increased informedness about science within this sample of South Africans. These variables include *educational attainment; geographic location; race* and *employment status.* Respondents with employment and a post matric education report the highest interest in any of the 7 scientific areas, 22.7% higher than the average across the sample (33.7%). Similarly urban respondents, that are white or black also report informedness levels 5.6% higher than the sample average. Respondents that are unemployed, living in rural areas, with lower educational attainment or within the coloured

[122] The age classification group 40-49 years reported the highest SUM informedness proportion (43.7%)

or Indian / Asian sub-samples report substantially lower informedness in science, 20.6% below the sample average. The variables for gender and age of respondent do not correlate significantly with the responses to this question. These predictors, along with additional variables will be included in the *multinomial logistic regression* modelling toward the output of a predictive model of interest in science measures in South Africa

These demographic variables will be explored in greater detail in terms of respondent response patterns within the next sections.

INFORMEDNESS IN SCIENCE BY RACE

A statistically significant association was reported between the *race* variable and respondent reported level of *informedness* (X^2=78.068, p < 0.001). White respondents generally reported higher informedness (54.7% - *19.9%) compared to black (41.9% - *14.1%); Indian / Asian (35.4% - *12.0%) and coloured respondents (32.0% - *6.1%). The response within the *very well informed* category was lowest within the coloured sub-sample, half that of the next highest race group (Indian / Asian).

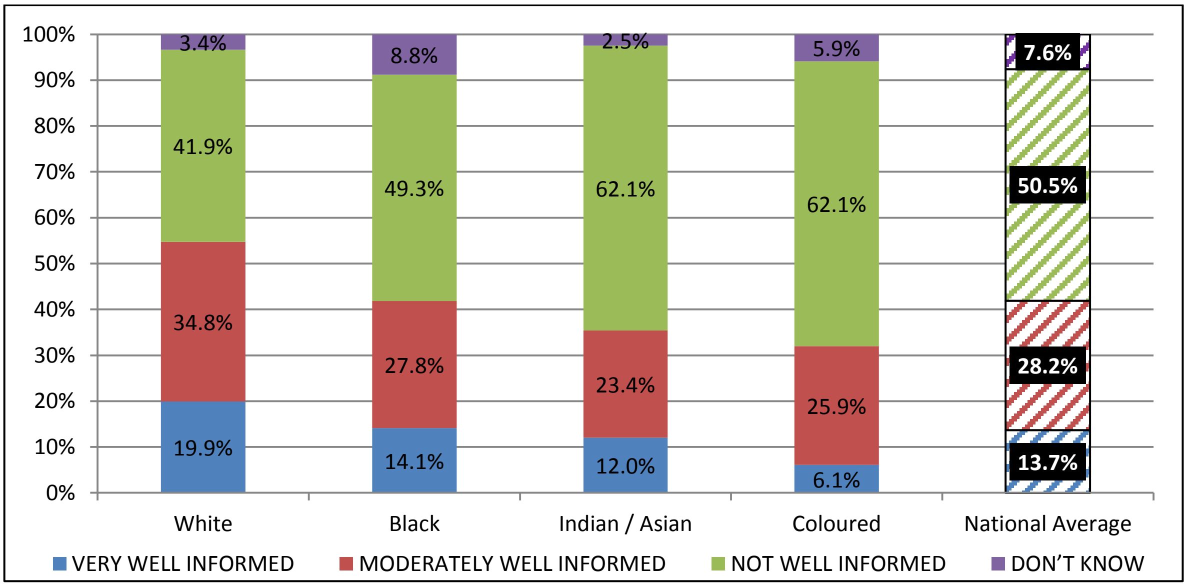


Chart 8.4: Average response by race group: *Informedness in Science* assessment

White respondents were significantly less likely to select a *not well informed* response compared to all other race classifications. Indian / Asian and coloured respondents were significantly more inclined to select a response within the *not well informed* option, compared to black and white respondents (see chart 8.4). Across all race classifications, black respondents provided the highest proportional response within the *don't know* category (8.8%).

The relative ranking of *informedness* by scientific area did show some variation by race classification. White respondents report the highest informedness proportion within the *technology and the* *internet* item (66.2% - *31.5%); followed by *climate change* (64.3% - *19.3%); *economics* (62.5% - *21.3%) and *energy* (55.9% - *20.7%).

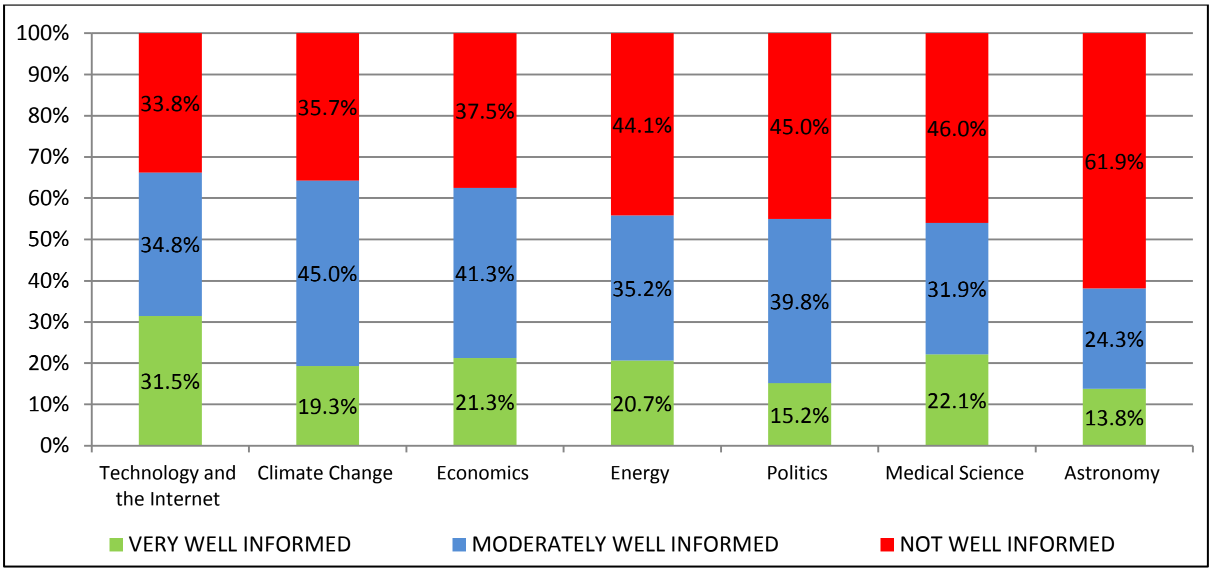


Chart 8.5: Average response by white subsample: *Informedness in Science* assessment

Within the white sub-sample, the response patterns for *informedness* in science generally reflect the ranking within the *interest* items. *Politics* (55.0%) was ranked proportionally higher than *medical science* (54.0%), however, the lowest informedness area was *astronomy* (38.1% - *13.8%).

Within the black sub-sample, the ranking of informedness items deviated from that of white respondents (see chart 8.6). *Politics* received the highest informedness response (54.4% - *17.2%); followed by *technology and the internet* (53.3% - *19.9%); *economics* (48.0% - *16.9%) and *climate change* (46.3% - *14.2%).

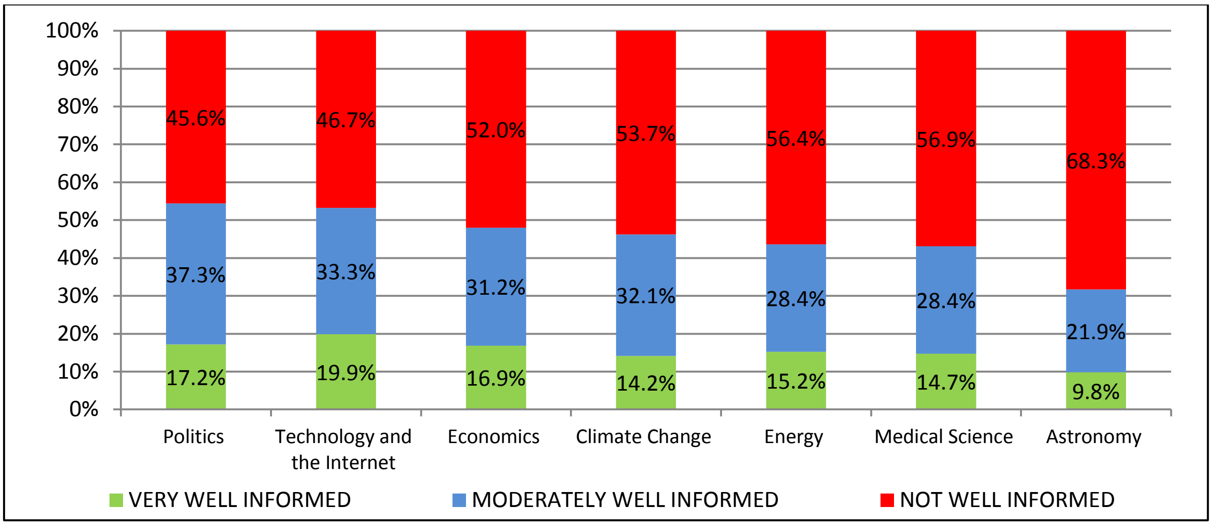


Chart 8.6: Average response by black subsample: *Informedness in Science* assessment

Medical science (43.1% - *14.7%) and *astronomy* (31.7% - *9.8%) were reported less frequently within the *well informed* categories. The items for informedness areas *economics*; *climate change*;

energy; *medical science* and *astronomy* similarly received the higher proportion of responses within the *not well informed* response option (see chart 8.6).

Indian / Asian respondents reported a different order of informedness item ranking (see chart 8.7). *Economics* received the highest informedness response (40.7% - *16.1%); followed by *technology and the internet* (40.3% - *16.0%); *medical science* (39.5% - *14.3%) and then *politics* (35.9% - *7.7%). This is somewhat of a deviation from reported interest within this sub-sample, wherein *politics* attracted the lowest reported interest (30.6%), despite the reported higher level of *informedness*. Among all race classifications, Indian / Asians report being least informed about issues related to *climate change* (34.7% - *12.7%). Overall, among this race group the area of lowest reported informedness remained *astronomy* (27.4% - *8.5%).

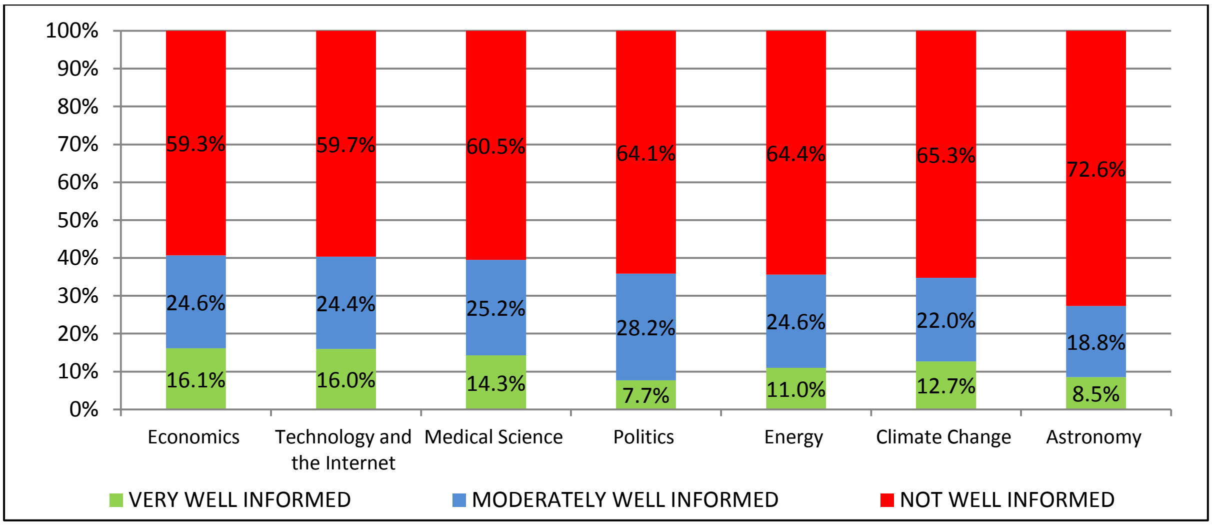


Chart 8.7: Average response by Indian / Asian subsample: *Informedness in Science* assessment

Respondents within the coloured race group recorded the lowest overall informedness across the questionnaire items. The largest proportion of *SUM informedness* selections was within the *technology and the internet* (47.1% - *12.1%) item; followed by *politics* (39.7% - *5.4%), *climate change* (36.3% - *6.3%) and *medical science* (32.7% - *6.1%).

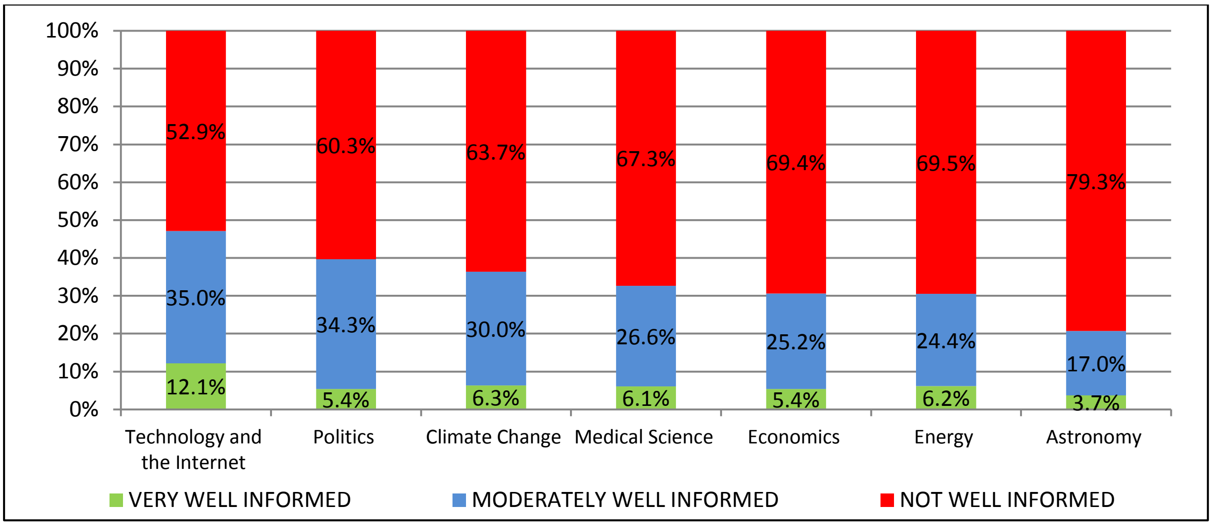


Chart 8.8: Average response by coloured subsample: *Informedness in Science* assessment

Respondents within the coloured sub-sample selected the *not well informed* option more frequently (see chart 8.8). Within 6 of the 7 items, coloured respondents selected this option in proportions exceeding 60%, with the highest being for *astronomy* (79.3%).

INFORMEDNESS IN SCIENCE BY GEOGRAPHIC LOCATION

Informedness in science was significantly associated with the *geographical location* variable (X^2=77.312, p < 0.001). Urban respondents reported significantly greater interest (46.1% - *15.5%) across all interest areas compared to members of the rural sub-sample (33.7% - *10.2%).

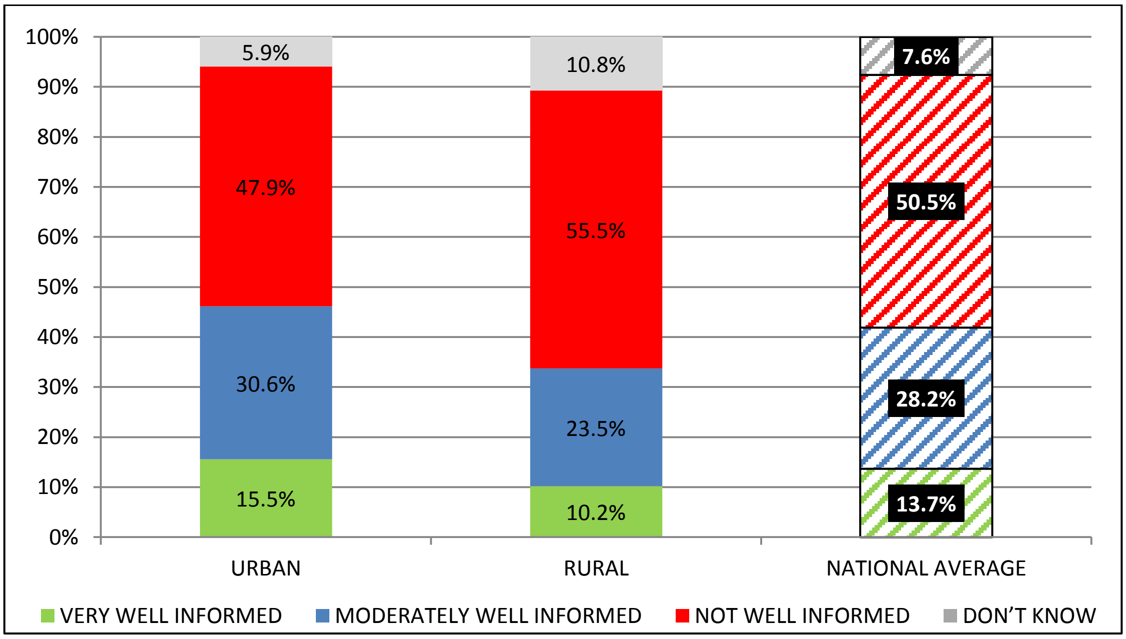


Chart 8.11: Average response by rural / urban location group: *informedness in science* assessment

A larger proportion of rural (55.5%) respondents selected the *not informed* response, compared to urban respondents (47.9%). Rural respondents also selected the *don't know* response twice as frequently compared to urban respondents.

Urban respondents showed the highest informedness within the *technology and the internet* item (58.8% - *22.7%); followed by *politics* (54.3% - *16.0%); *economics* (51.3% - *18.3%) and *climate change* (50.6% - *15.3%). The items that achieved a greater proportion of *not informed* responses include: *medical science* (52.9%); *energy* (53.0%) and *astronomy* (66.2%).

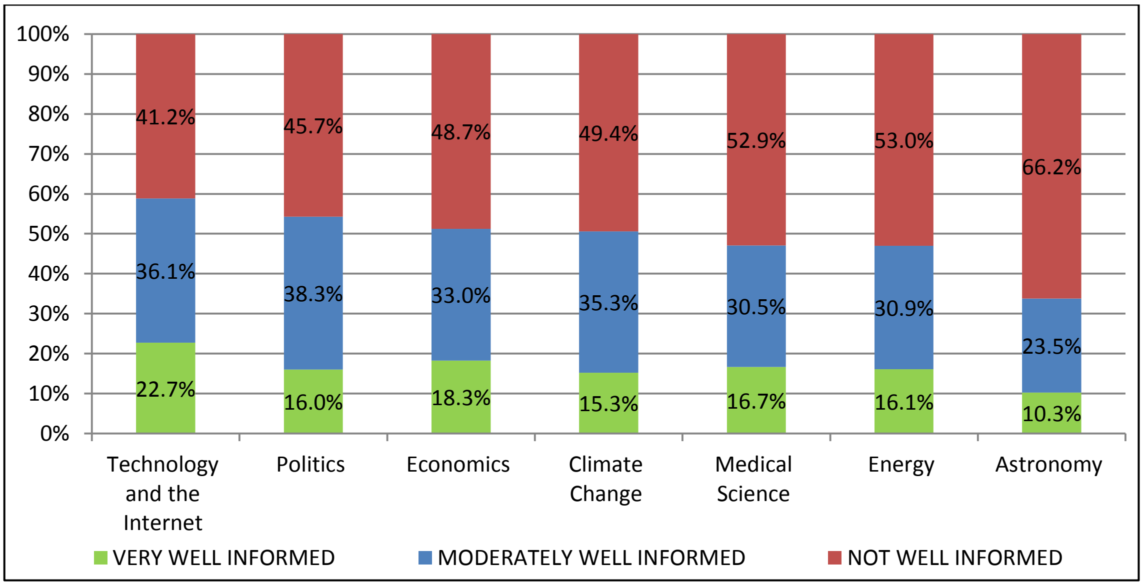


Chart 8.12: Average response by urban sub-sample: *informedness in science* assessment

Among the rural sub-sample the response patters within the informedness categories did differ compared to the urban respondents. The item attracting the highest proportion of *informedness* responses was *politics* (47.4% - *13.3%), followed by *technology and the internet* (43.0% - *15.1%); *economics* (39.3% - *11.1%) and *climate change* (39.1% - *10.7%).

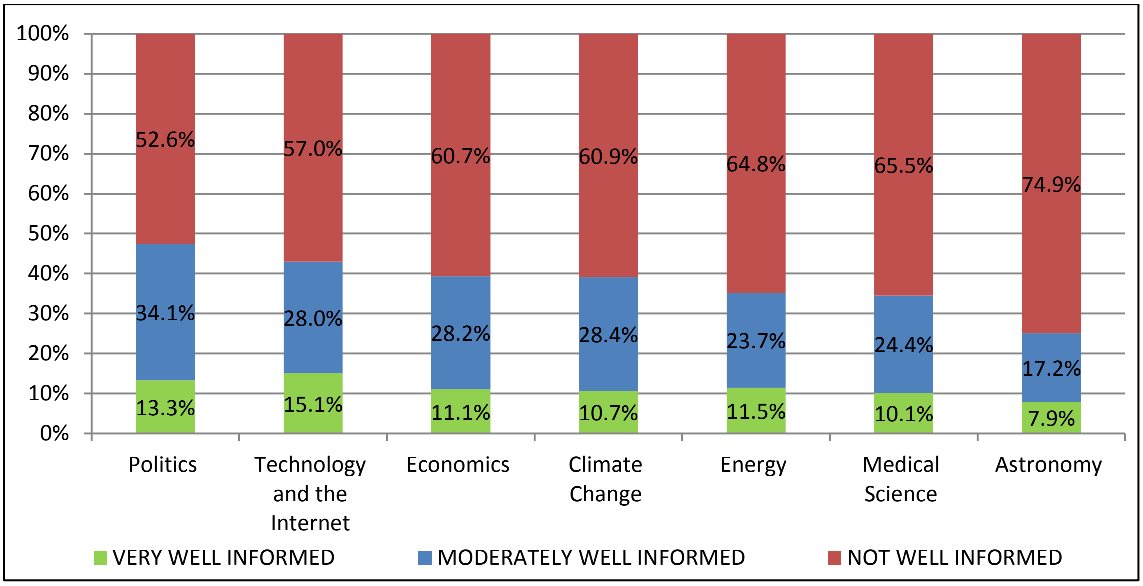


Chart 8.13: Average response by rural sub-sample: *informedness in science* assessment

The recorded response for *medical science* (64.8%) and *energy* (65.5%) attracted a larger proportion of *not well informed* responses. However *astronomy* (74.9%) remained the scientific area within which rural respondents selected a larger proportion of *not well informed* responses (see chart 8.13).

<u>INFORMEDNESS IN SCIENCE BY EDUCATIONAL ATTAINMENT</u>

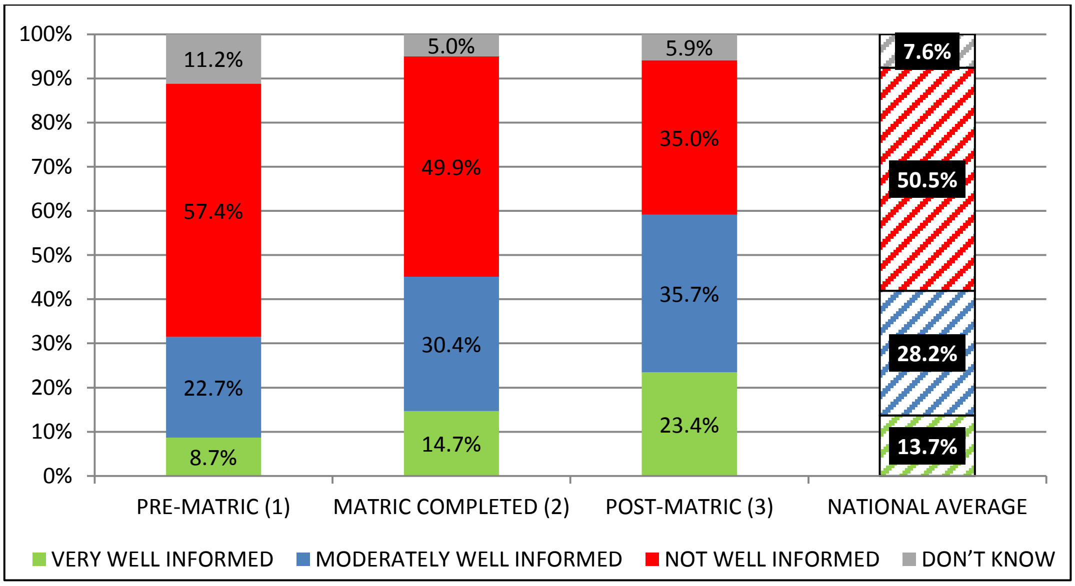


Chart 8.14: Average response by educational attainment group: *informedness in science* assessment

The level of respondent educational attainment has been shown to demonstrate a statistically significant association with level of informedness in science (X^2=180.875, p < 0.001). Respondent reported levels of informedness across the 7 items show a distinct pattern of increase with respondent educational attainment level (see chart 8.14). Respondents within the pre-matric (31.5% - *8.7%) educational attainment category demonstrated significantly lower levels of informedness compared to those within the post-matric (59.1% - *23.4%) group. Among the pre-matric group, the aggregate level of informedness was 10.5% below the *SUM informed* level of the national average reported earlier (41.9%). Among respondents within the post-matric category, average informedness was reported at 17.2% above this national average informedness (across all 7 items). Those within the pre-matric educational group selected the *don't know* response option twice as frequently, compared to those with a completed matric and those with post-matric educational attainment.

Respondents with a pre-matric education showed the greatest informedness proportion within the area of *politics* (41.9% - *9.5%); followed by *technology and the internet* (35.4% - *10.8%); *climate change* (32.6% - *8.7%) and *economics* (32.0% - *8.5%). Within this sub-sample, 6 of the 7 items attracted a larger proportion of response within the *not well informed* category. This response proportion ranged from 54.1% (*technology and the internet*) to 65.7% (*astronomy*).

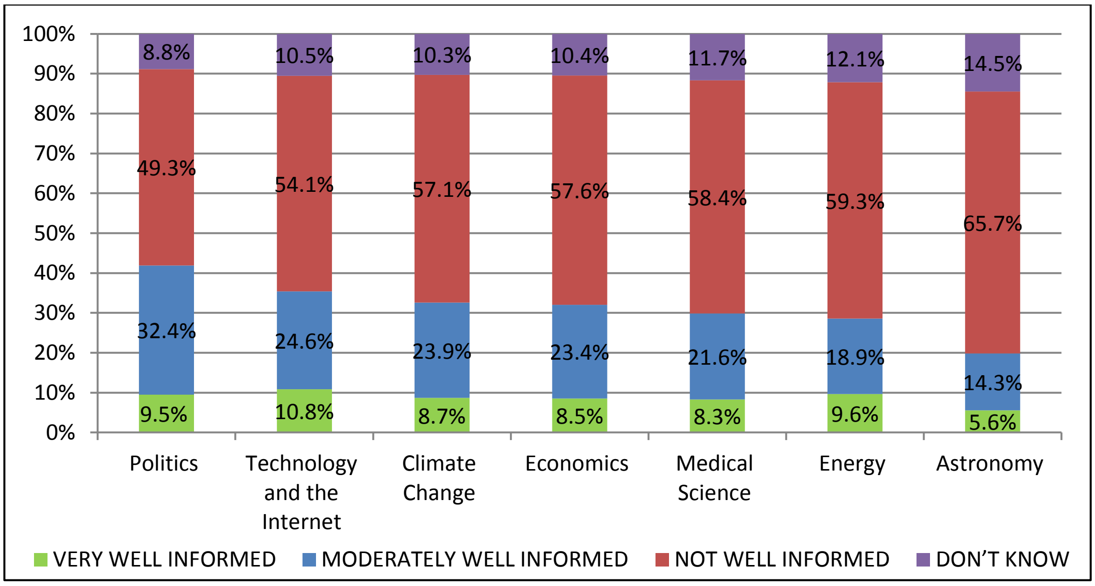


Chart 8.15: Average response by pre-matric educational attainment subsample: *informedness in science* assessment

Respondents within this educational group more often selected the *don't know* response, compared to the matric complete and post-matric group. All items within the question set attracted greater than 8.0% response within the don't *know* response, while the *astronomy* item attracted a response proportion of 14.5% within the *don't know* option.

Respondents with a completed matric educational attainment level reported a larger share of response within one of the *informed* options.

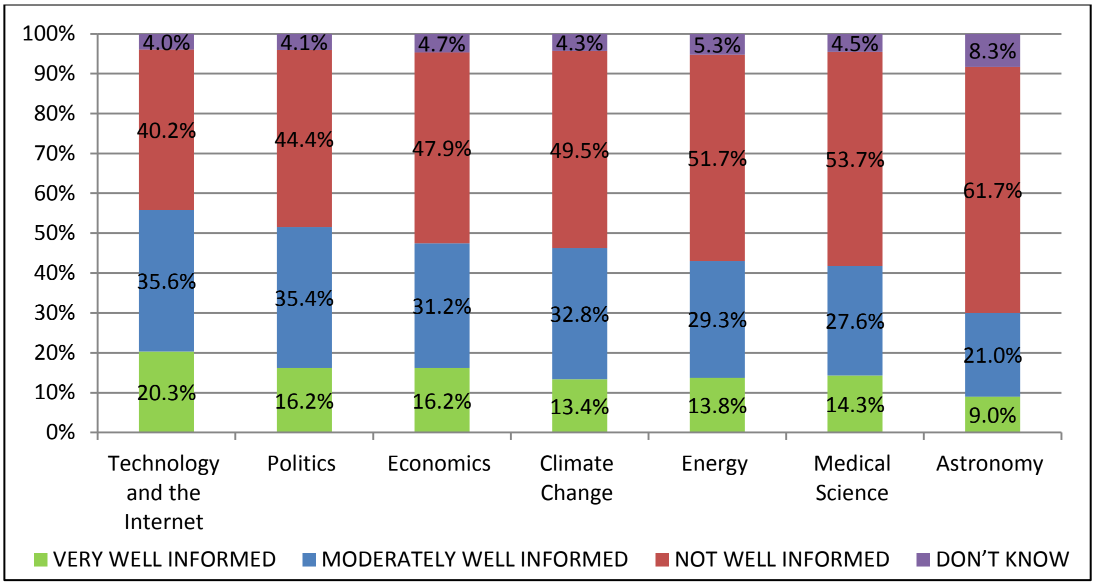


Chart 8.16: Average response by matric completed educational attainment: *informedness in science* assessment

The informedness area attracting the largest proportion of response was again *technology and the internet* (55.8% - *20.3%) followed by *politics* (51.5% - *16.2%); *economics* (47.4% - *16.2%) and *climate change* (46.2% - *13.4%).

The areas of *energy*, *medical science* and *astronomy* attracted the highest proportions of response within the *not informed* option (see chart 8.16). The response patters for selections of a *don't know* response was generally lower within this educational attainment group, where the largest response proportion was within the *astronomy* item (8.3%).

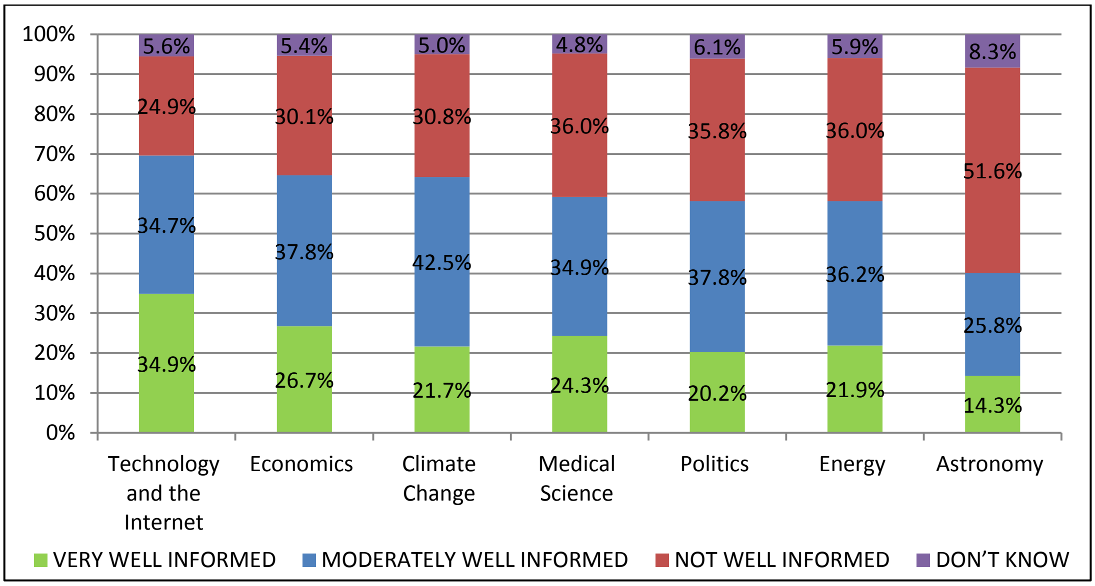


Chart 8.17: Average response by post-matric educational attainment: informedness in science assessment

Respondents with a post-matric education displayed the highest overall level of informedness. Within this educational classification, levels of informedness were highest in the *technology and the internet* (69.6% - *34.9%) followed by *economics* (64.6% - *26.7%) and *climate change* (64.2% -

*21.7%). Interest areas for *medical science, politics* and *energy* attracted a similarly high *SUM informedness* level. The item attracting the lowest overall proportion of informedness selections was *astronomy*, wherein 51.6% of respondents indicated a *not well informed* or *don't know* (8.3%) response.

Conclusion

Within the national sample, fewer respondents report being adequately informed within the seven areas of science included. This is particularly important when compared to the reported level of interest (chapter seven). Across all 7 items, an average of 45.3% of the sample report being adequately informed within all the scientific areas. This includes 14.3% that indicate they are *very well informed* while 30.5% indicate a *moderate* level of informedness. This is not an unexpected result as *informedness* usually lags *interest* in numerous studies of this nature. The areas of greatest informedness include *technology and the internet*; *politics* and *economics*. Across the entire sample, the areas of least *informedness* were reported to be *medical science* and *astronomy*.

Race classification was a significant factor within reported informedness about science. White respondents reported greater informedness compared to all other race groups, while coloured respondents report the lowest average informedness across the all questionnaire items. Within the coloured sub-sample, respondents were 3.2 times less likely to indicate a *very well informed* response compared to the white sub-sample. Reported informedness areas were also differentiated by race classifications. All race groups reported a higher proportion of informedness with regards to *technology and the internet*. Among the white sub-sample this was followed by *climate change* and *economics*, while coloured respondents reported *politics* then *climate change.* Black respondents reported greater informedness in the area of *politics* then *technology and the internet* followed by *economics*. Within the Indian / Asian sub-sample the highest ranked informedness area was *economics* then *technology and the internet* followed by *medical science.* Across all race groups *astronomy* remained the area of lowest informedness.

Gender was not found to be significantly associated with informedness about science. Overall level of informedness for males was 44.1% while for females this was 39.8%. Both males and females reported *technology and the internet* and *politics* as scientific areas they are most informed about. Males and females differed significantly in terms of reported informedness in the areas of *politics* and *economics*.

Urban respondents indicated a greater level of informedness across all items, compared to rural respondents. The scientific areas of *technology and the internet*, *politics* and *economics* represented the highest informedness area for urban respondents while within the rural sub-sample informedness in *politics* was greater than for *technology and the internet. Astronomy* continued to be the area of least informedness within both rural and urban location groups.

Informedness in science increased with similar increases in educational attainment across all demographic classifications. Respondents with a completed matric and post matric education reported *technology and the internet* as the area of greatest informedness. Within the pre-matric sub-sample however, *politics* was the area respondents felt most informed about. The next most frequent selections for all educational attainment groups were within the areas of *economics* and *climate change*, however proportionality varied across groups.

The age group of respondents was found to be significantly associated with reported informedness about science. Informedness was higher within the younger age classifications and decreased significantly for respondents older than 59 years. The overall highest level of informedness was within the 40-49 years age category. The area of greatest informedness for respondents younger than 39 years was consistently *technology and the internet*; however for those older, the area of highest informedness did show some variation. As within other demographic classification, *astronomy* was reported as the area of lowest informedness.

The levels of *interest* and *informedness* did demonstrate some lag, wherein 6 items reflected a higher proportion of respondents reporting *interest* compared to respondents reporting *informedness*. The notable exception here is the item for *politics*, where overall the national sample indicated the same level of *interest* and *informedness* within the questionnaire items. The largest gap between reported *interest* and *informedness* was recorded within the *energy* item.

Chapter Nine

Descriptive Survey Results:

Sources of Information about Science

The better educated we are and the more acquired information we have, the better prepared shall we find our minds for making great and fruitful discoveries.

Claude Bernard (1865)

Introduction

The general level of access to sources of information relating to science is a key area of investigation toward fostering a more holistic appreciation of the overall South African public understanding of science. Beyond formal education, *informal sources* of science education have become increasingly important toward the development of a citizenry appropriately skilled to meet the challenges of the 21st century (The Wellcome Trust; 2000). Sources of scientific information, via the media, public and private information streams are critical in expanding and solidifying the public understanding and application of scientific concepts across a broad range of fields. However within the developing world context, access to information sources may be limited due to interrelated sociodemographic factors that may limit accessibility. Beyond accessibility, related concepts of preference, trust in information sources as well as language and general literacy further contribute to the patterns of active science information seeking behaviour within the general public(s).

OVERALL NATIONAL RESULTS FOR SCIENCE INFORMATION SOURCES ITEMS[123]

Overall results are presented for all responses within the *most frequently* and *occasionally* response categories in chart 9.1. The most frequently selected response as the information source where respondents encountered scientific information most often was *Radio* (69.4%).

This was followed by *free-to-air television* services (65.0%) and then *other people* (60.0%). The selections, across the entire sample resulted in *newspapers* (60.2%) and *satellite television* (50.2%) appearing above *social media* (43.2%). The response options for *books / magazines* (49.2%) as well as *government announcements* (38.4%) received lower proportions of response sections. The items receiving the lowest response as a source of scientific information were online based services: *blogs* (33.0%); *institutional websites* (28.9%) and *news websites* (28.2%).

[123] The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

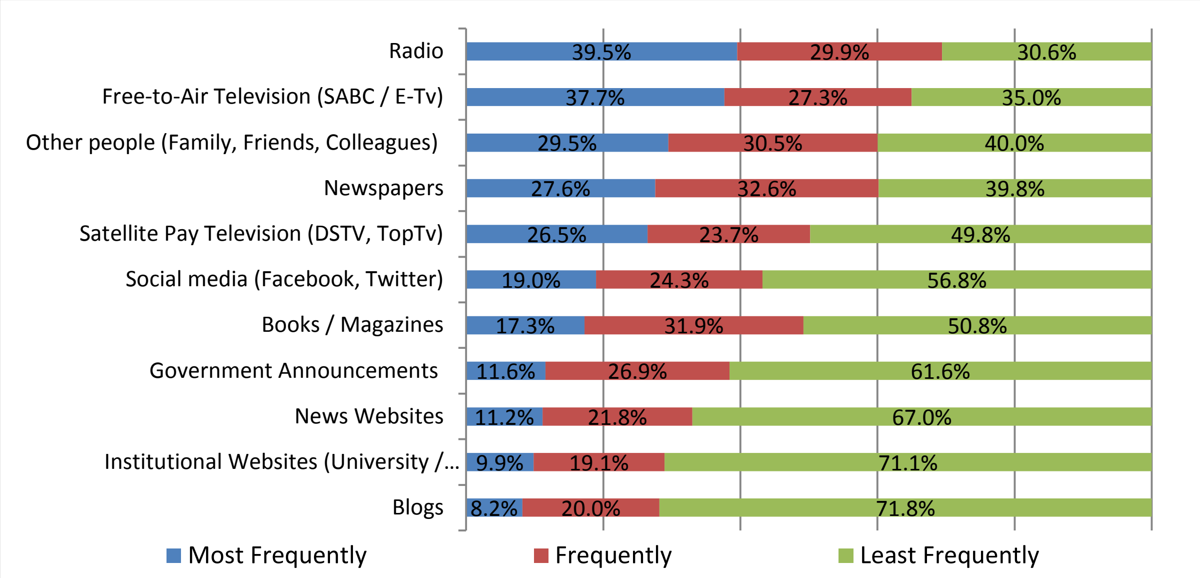


Chart 9.1: Overall result: South African information sources on science assessment (Khayabus Wave 2, 2015)

Taking all response frequencies into account[124] a ranking of information sources for the overall sample within this study could be developed (see chart 9.2). Minor variations to the response presented in chart 9.1 above are evident within the ranking of scientific information sources. The information sources most frequently reported by South Africans to access scientific information was *radio* (86.3%) followed by *newspapers* (82.8%) and *free-to-air television* (82.5%).

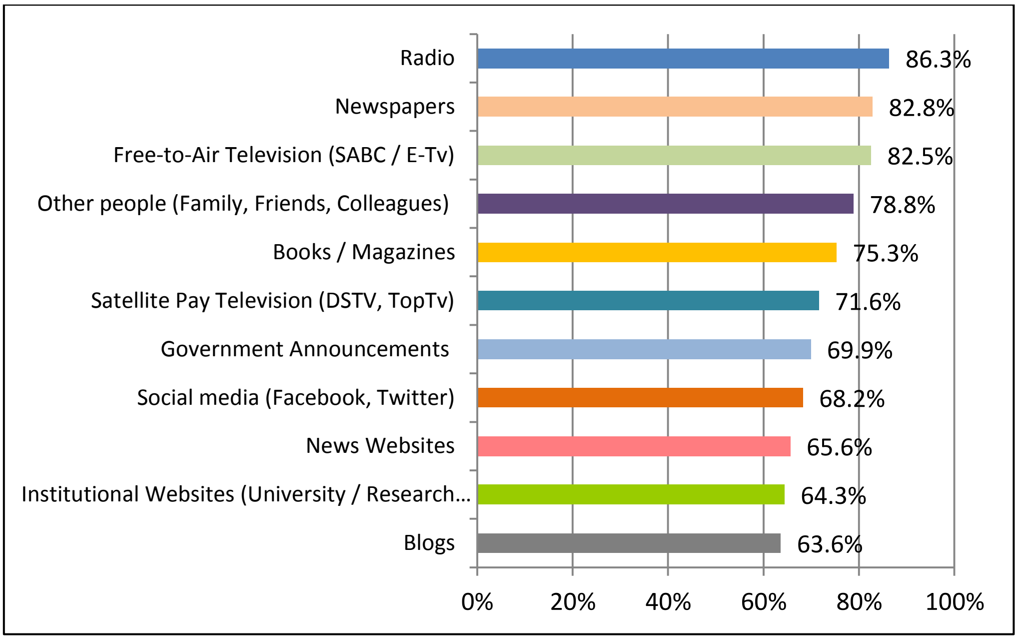


Chart 9.2: Overall result: Highest ranked science information sources

A higher than expected ranking was realised by "human" sources of information, with the *other people* category being selected by 78.8% of respondents, as the 4th most frequently accessed source of scientific information. Government announcements featured 7th on the ranking list, below *books /*

[124] Responses for *Most Frequently*, *Occasionally* and *Least Frequently* – however excluding all *Don't Know* responses.

magazines (75.3%) and *satellite television* (71.6%). All online information source categories featured at the bottom of the ranking order, with *blogs* being selected as the least accessed scientific information source. The relatively low ranking of online information sources may be influenced by issues relating to access and affordability, to be discussed later.

Four categories of information channels have been identified as particularly important. These include Broadcast (*Television* and *Radio*); Print (*Books/ Magazines* and *Newspapers*); Human (*Other People* and *Government announcements*) as well as Online (*News Websites*, *Institutional Websites*, *Blogs* and *Social Media*)[125].

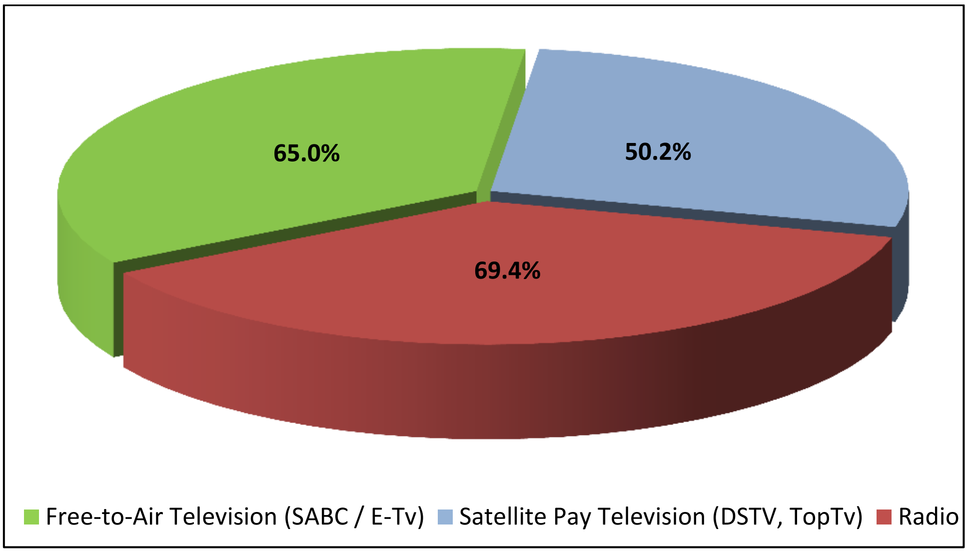


Chart 9.3: Ranking of *Broadcast* science information sources

The *broadcast* group consisted of both *free-to-air television* as well as *satellite pay television* services and included *radio*. As noted previously *radio* was the most frequently selected overall source of scientific information, receiving 4.4% more frequency selections than *free-to-air television* (see chart 9.3). Within this information source group, *free-to-air television* (65.0%) was ranked higher than *satellite pay television* (50.2%). These patterns may be associated to sociodemographic and access factors as there are significant cost variations between the three types of broadcast information sources. Due to its relative low cost, wide coverage and greater variation of listening options (radio stations, languages and talk / music formats) radio has consistently been reported as the most important source of information across many similar international studies.

The *print* information source group included *newspapers* as well as *books / magazines*. Within the overall national result, *newspapers* featured more frequently as a science information source compared to *books or magazines* (see chart 9.4). This result was highly consistent across all

[125] Values in charts in this section are proportional values from overall rankings and will not sum to 100%

demographic classifications, wherein newspapers were reported with increased frequency as a source of science information compared to books and magazines. While in selected age and educational attainment classification groups the proportional variation between *newspapers* and *books / magazines* was smaller, overall the pattern presents across all demographic classifications. This may in part be due to accessibility and cost associated with *books / magazines*, while *newspapers* remain widely available and carries a relatively low associated cost factor.

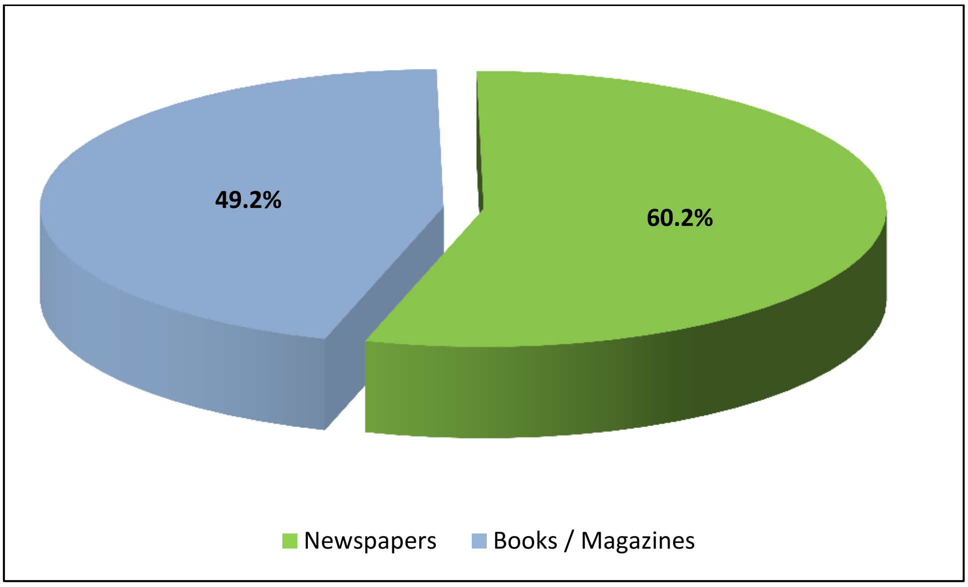


Chart 9.4: Ranking of *Print* science information sources

Human Sources of information was made up of the category *other people* and included information received from *family, friends or colleagues*. The other response item making up this information source category is *government announcements*, which includes interactions with office bearers and information received via civic meetings and announcements. Within this category, *other people* was more frequently selected as an important source of scientific information, compared to *government announcements* (see chart 9.5).

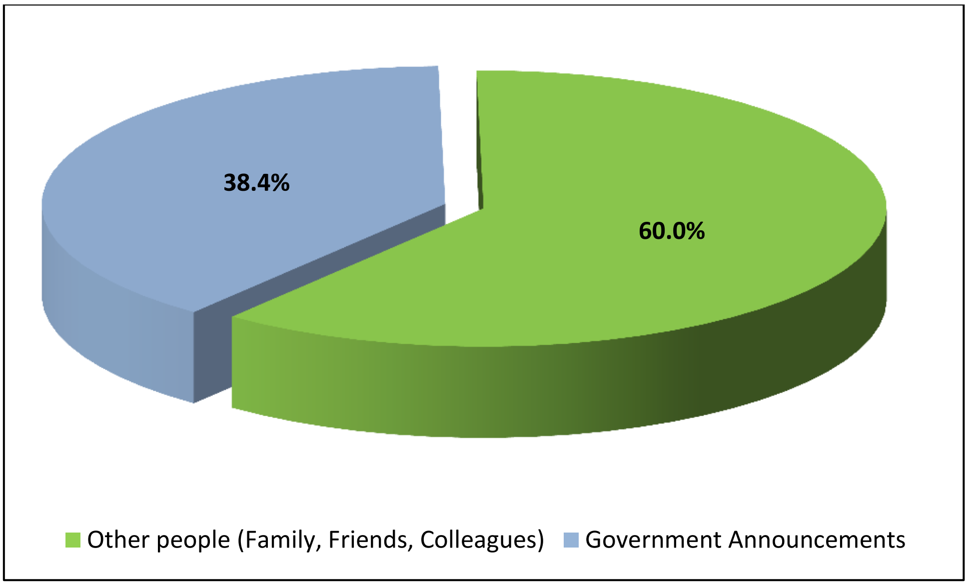


Chart 9.5: Ranking of *Human* science information sources

Within the ranking this results is evident (chart 9.2) as the *other people* item was ranked much higher (78.8%) in the overall national ranking of science information sources, compared to government announcements (69.9%).

The final channel for science information is the *online* group. This group consists of *news websites*; *institutional websites*; *blogs* and *social media*. At the national level all four items within this group were ranked the lowest within the most frequent source of science information, however within this group there are some variations in the proportional frequencies realised.

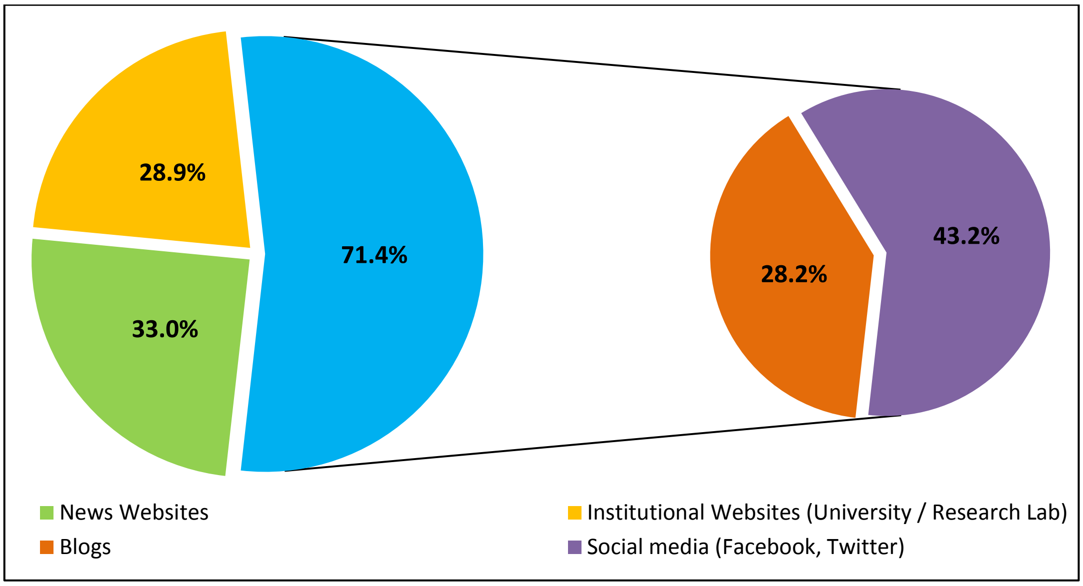


Chart 9.6: Ranking of *Online* science information sources

Online sources of scientific information have been classified into 2 sub-groups: *websites and social* media platforms. Within the website sub-group, *institutional websites* (research labs, university websites) was ranked lower than *news websites* as a source of scientific information. This is likely due to the highly specialised audience and appeal of *institutional websites* and the relatively larger online presence of *news websites* (see chart 9.6).

Within the social media sub-group, *blogs* received the lower proportion of response compared to *social media* platforms. *Social media*, due to its mobile platforms and wider reach and information sharing capabilities have over the last few years become an increasingly important source of news and information, which is echoed within this result.

Results for the science *information sources* measure will be further explored by the various demographic classifications within the next part of this chapter. The data will be presented within the following classifications: *race group; gender; geographic location; educational attainment* and *age*. Table 9.1 presents the results for the ranking of the top four overall national most frequently reported science information sources. This is further disaggregated by demographic classification groups; however it is important to note that these top four national ranking positions are not reflected in all demographic classifications.

	OVERALL NATIONAL RANKING ORDER					
	Radio	Newspapers	Free-to-Air TV	Other people	Lowest Ranked Source	N
NATIONAL	**86.3%**	**82.8%**	**82.5%**	**78.8%**	***Blogs* (63.6%)**	**3 486**
RANKING VARY WITHIN DEMOGRAPHIC CLASSIFICATIONS						
RACE	**N = 3 486**					
BLACK	85.9%	81.4%	81.0%	75.9%	***Blogs* (60.4%)**	**2 523**
WHITE	92.2%	92.9%	91.2%	93.6%	***Blogs* (79.4%)**	**408**
INDIAN / ASIAN	94.2%	93.4%	93.4%	91.7%	***Blogs* (72.7%)**	**121**
COLOURED	81.3%	78.6%	80.2%	77.9%	***Blogs* (64.7%)**	**434**
GENDER	**N = 3 486**					
FEMALE	85.0%	82.1%	81.9%	78.6%	***Blogs* (62.4%)**	**1 747**
MALE	88.0%	83.9%	83.5%	79.4%	***Blogs* (65.0%)**	**1 739**
GEOGRAPHIC LOCATION	**N = 3486**					
URBAN	88.6%	86.3%	85.2%	82.4%	***Blogs* (66.0%)**	**2 297**
RURAL	82.0%	76.1%	77.3%	71.8%	***Blogs* (59.0%)**	**1 189**
EDUCATION	**N = 3486**					
PRE-MATRIC	81.7%	74.4%	75.8%	70.9%	***Blogs* (53.5%)**	**1 369**
MATRIC COMPLETED	88.5%	86.9%	85.6%	82.4%	***Blogs* (66.7%)**	**1 578**
POST-MATRIC	91.8%	92.4%	90.5%	88.1%	***Blogs* (77.4%)**	**539**
AGE	**N = 3 472**					
<20 YEARS	86.5%	80.0%	84.7%	78.2%	***Institutional Websites* (77.4%)**	**170**
20-29 YEARS	86.6%	84.1%	84.0%	80.7%	***Blogs* (66.8%)**	**1 101**
30-39 YEARS	85.7%	82.8%	81.6%	78.1%	***Blogs* (63.0%)**	**956**
40-49 YEARS	88.0%	84.8%	84.1%	79.8%	***Blogs* (63.2%)**	**598**
50-59 YEARS	84.9%	81.5%	79.8%	78.5%	***Blogs* (62.1%)**	**372**
60+ YEARS	85.1%	76.4%	77.8%	71.3%	***Blogs* (52.7%)**	**275**

Table 9.1: Abridged ranking of *Science Information Sources* questionnaire items by demographic classifications

Among the national sample of 3 486 respondents, the race group classification variable was found to be significantly associated with type and frequency of access to varied science information channels (X^2=95.812, p < 0.001). The frequency of encountering science information across the 11 science information sources displayed similar patterns for the different race group classifications. Respondents within the white sub-sample reported an average *SUM Frequently*[126] proportion equal to 59.5%, compared to Indian / Asian (51.6%); black (46.8%) and coloured (38.2%) respondents, across all 11 items. There were, however, noted variations in the ranking order of science information sources among race group classifications.

Gender group classification did not demonstrate a statistically significant association to the type and frequency of science information channels encountered within this sample (X^2=4.774, p > 0.05). There were no significant variations in the ranking order of science information sources between gender groups. Similarly, while female (48.5%) respondents did offer a greater proportion of *SUM Frequently* response across the 11 items, compared to males (47.1%), this difference was however not found to be statistically significant.

The rural / urban classification was found to be statistically associated with the responses to the science information source items (X^2=71.268, p < 0.001). A similarly high level of statistical significance was demonstrated within the *Province* location variable (X^2=289.807, p < 0.001). Within the Provincial location variable the highest proportion of respondents reporting a *SUM frequently* response was in the Gauteng province (57.0%). The lowest proportional response within the *SUM frequently* options, across, was recorded for the Northern Cape (26.8%). Similarly, urban respondents (51.8%) reported accessing a higher count and frequency of science information sources, compared to rural respondents (39.0%).

The level of respondents' educational attainment was significantly associated to respondent selections on the science information sources items (X^2=283.615, p < 0.001). Respondents with increased educational attainment reported higher frequencies of encountering science information across the 11 items in this question set. Individuals with post-matric educational attainment more often (62.8%) reported a SUM *Frequently* response across the 11 science information source items, compared to respondents within the pre-matric education group (36.2%).

Age group classification of respondents was similarly found to be significantly associated with the sources of science information items (X^2=31.517, p < 0.001). Across all 11 questionnaire items, SUM *frequently* responses show a general pattern of increasing proportionality for respondents younger

[126] *SUM Frequently* = the sum of the *Most Frequently* and *Occasionally* responses. Excludes *Least Frequently* and *Don't Know* response selections.

than 50 years old. Among respondents older than 50 years old there appears to be a decline in *SUM frequently* response, with respondents 60+ years reporting the lowest overall response average for all science information source items (39.2%).

EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH SCIENCE INFORMATION SOURCES

In computing the CHAID analysis on the sources of science information data, the analysis adopted the composite score across all science information source items, toward completing this statistical procedure. The following categorical variables were entered into the computation: *gender; race; household income; educational attainment; geographic location (rural-urban); employment* and *age.*

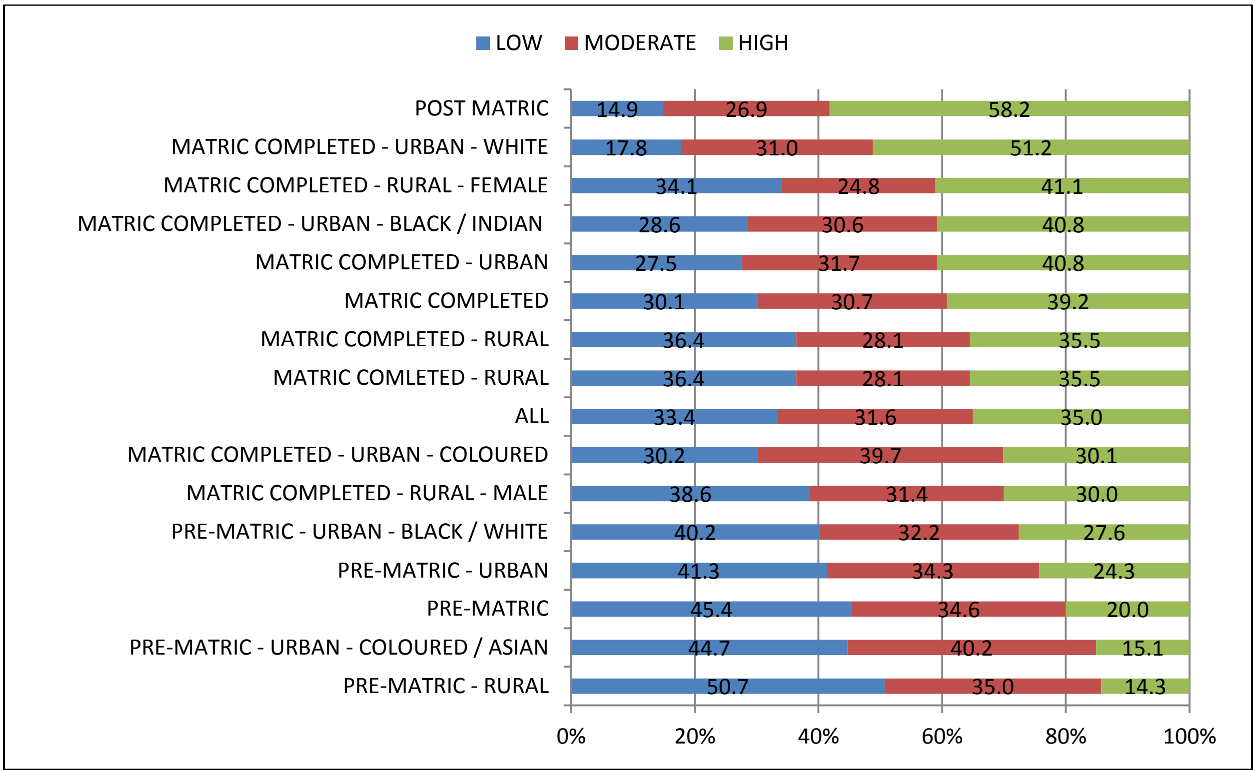


Figure 9.1: Output of CHAID analysis: Science Information sources

The output of the analysis highlights four key variables that may serve as predictors of response on sources of science information questions. These include: race; educational attainment level; geographic location as well as gender. Figure 9.1 details the output for the CHAID analysis and illustrates that respondents with a completed matric education (or higher), living in urban areas and within the white race group encounter more scientific information sources than others. The strongest predictor however remains educational attainment, where respondents with a post-matric education achieve a score 23.2% above that of the sample average (All). Conversely, respondents with pre-matric education (58.2%), within rural areas achieve a score 43.9% lower than those with a post-matric education (14.3%).

These demographic variables will be explored in greater detail in terms of respondent response patterns within the next sub-sections.

SCIENCE INFORMATION SOURCES BY RACE

Race classification was shown earlier to have a significant association with respondent selections within the science information sources question (X^2=95.812, p < 0.001). Within the three response categories, the options for *most frequently* and *occasionally* have been summed into a combined *Sum Frequently* response with the discussions of these results (questionnaire response categories - see chart 9.7) . White respondents reported the highest proportion of *SUM frequently* responses (59.5%), compared to Indian / Asian (51.6%); black (46.8%) and coloured respondents (38.2%). The highest proportion of *least frequently* responses was selected by members of the coloured sub-sample (61.8%).

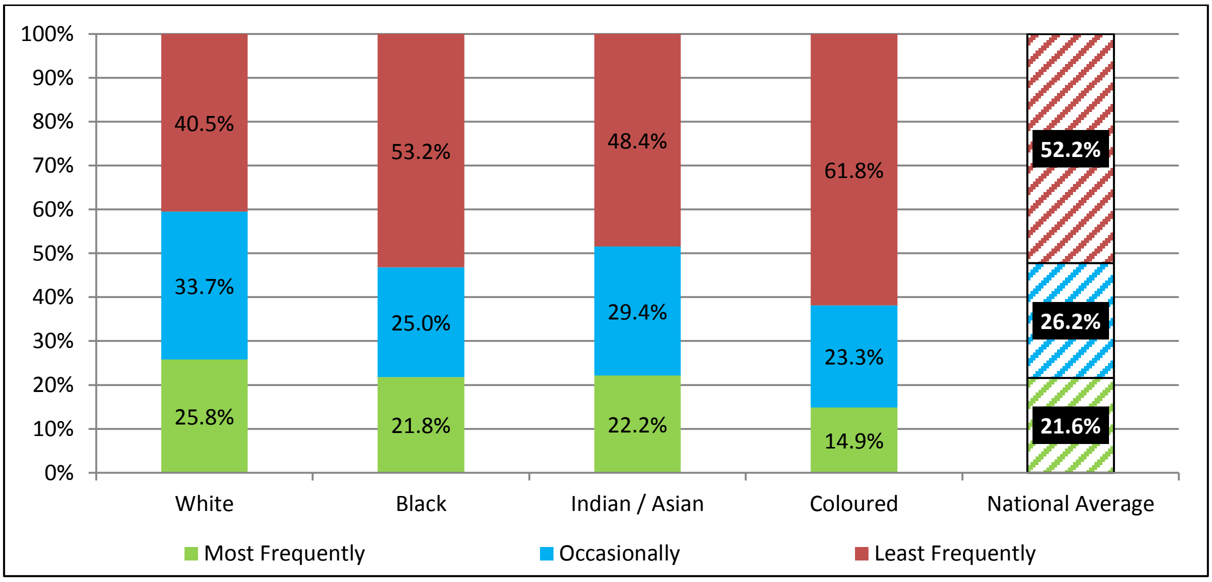


Chart 9.7: Average response by race group: *science information sources*

White (40.5%) and Indian (48.4%) respondents were less likely to select a not frequently response compared to black (53.2%) and coloured (61.8%) respondents. Similarly, black and coloured respondents were more likely to respond below the level of the national average compared to Indian / Asian and white respondents.

Within the white sub-sample, the most selected source of science information was *other people* and *newspapers*, both achieving a *SUM frequently* proportion of 74.9%. However despite this more white respondents selected the *most frequently* response within the *other people* (36.6%) option compared to *Newspapers* (34.6%). Among this demographic, the next three highest proportional response was within the *satellite pay television* (74.7%); *radio* (69.7%) and *books / magazines* (69.1%) categories.

Among black respondents, the profile of selections within the 11 questionnaire items was different to that of the white sub-sample. The most frequently selected response within this sub-sample was *radio*, receiving a proportional *SUM frequently* response of 72.1%. This selection was followed by *free-to-air television* (68.5%); *newspapers* (58.9%) and *other people* (58.3%).

The selection frequencies for the Indian / Asian sub-sample reflected that *radio* (67.5%) was the most often selected science information source, with 37.7% selecting the *most frequently* response while 29.8% of the sub-sample selected the *occasionally* option. Indian / Asian respondents then most often selected *other people* (64.0%); *satellite pay television* (63.9%) and *newspapers* (62.8%).

The coloured sub-sample most frequently selected the *free-to-air television* option, with a *SUM frequently* response of 54.6%. The next 3 highest selections among coloured respondents included: *radio* (53.5%); *other people* (51.8%) and *newspapers* (50.7%). Among all race groups, coloured respondents demonstrated the lowest overall frequency in encountering science information across the 11 questionnaire items included.

Adopting the *sum frequency* of all valid responses a ranking order of information sources was achieved. Across all four race classifications there were variations within the ranking order of the most frequent source of scientific information.

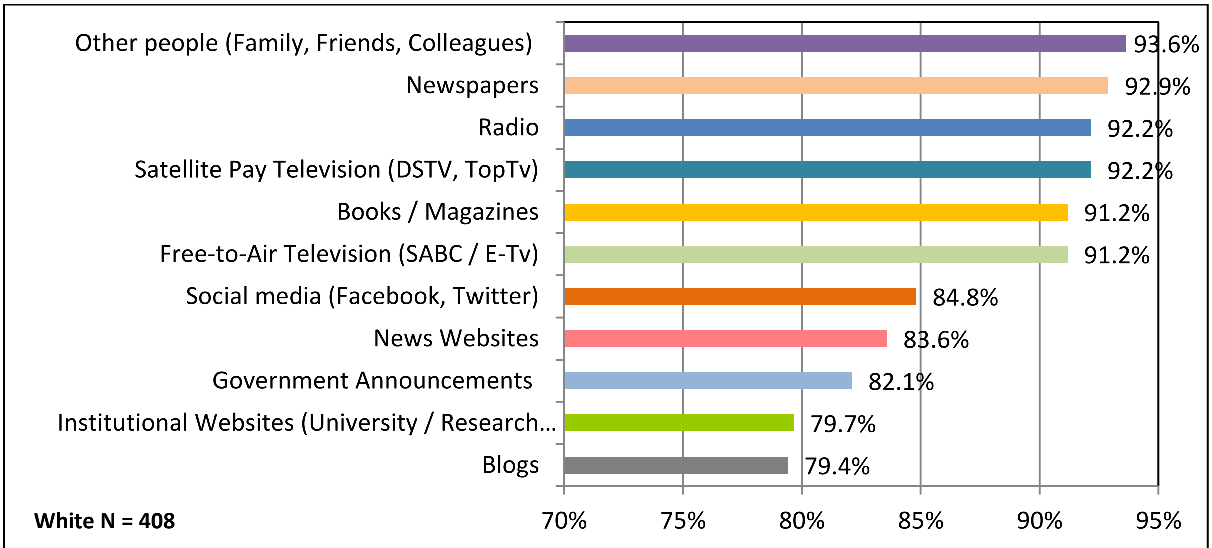


Chart 9.8: Highest ranked science information sources: white subsample

Among white respondents the most frequently selected source of science information was *other people* (93.6%); followed by *newspapers* (92.9%); radio (92.2%) and *satellite pay television* (92.2%). Despite the similar ranking of *radio* and *satellite television* services, more white respondents reported *satellite pay TV* (46.3%) within the *most frequently* response category than was selected for *radio* (33.2%). *Books / magazines* and *free-to-air television* were ranked with similar frequency, while social media was ranked 7th overall within this demographic (see chart 9.8). The science information sources receiving the lowest overall ranking within this demographic was *institutional websites* (79.7%) and *blogs* (79.4%).

The ranking order among black respondents is different from that of white respondents. Within this sub-sample, the highest sum frequency was recorded within the *radio* (85.9%) option followed by *newspapers* (81.4%); *free-to-air TV* (81.0%) and *other people* (75.9%).

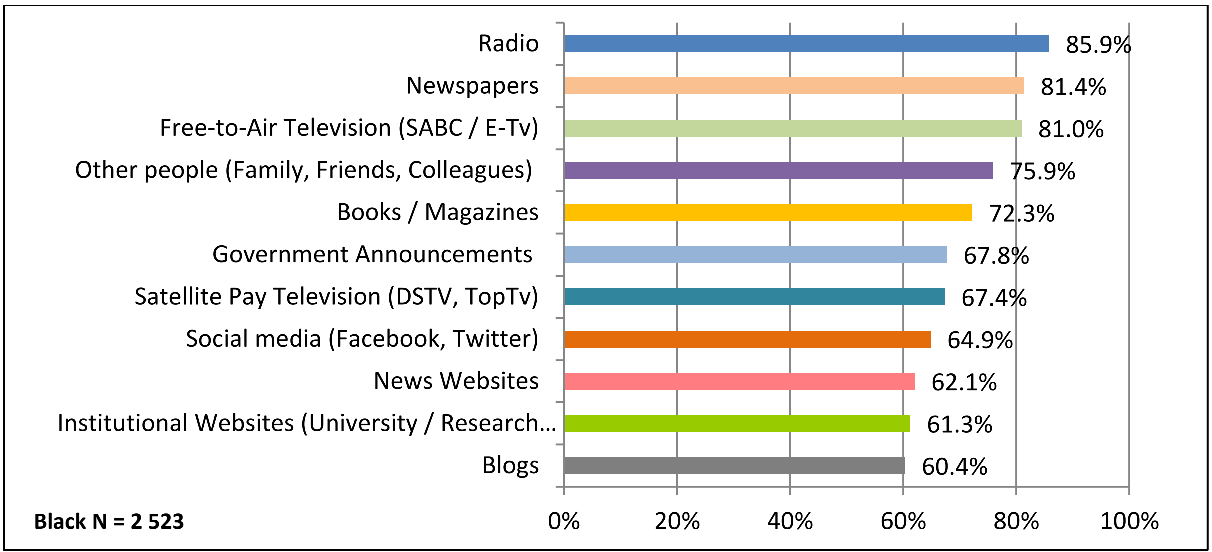


Chart 9.9: Highest ranked science information sources: black subsample

Social media sources of scientific information was ranked 8th among the black sub-sample (64.9%), followed by all other online information sources (see chart 9.9). *Blogs* received the lowest overall ranking within this demographic, with 60.4% of black respondents indicating any frequency of information encountered via this information sources.

Within the Indian / Asian sub-sample *radio* (94.2%) was the highest ranked science information source (see chart 9.10). This was followed by *newspapers* (93.4%); *free-to-air TV* (93.4%) and *other people* (91.7%). There was some distinction to be made between the ranking of *newspapers* and *free-to-air TV*, where a larger proportion of respondents selected *newspapers* (32.7%) within the *most frequently* response category, compared to selections under *free-to-air TV* (22.1%).

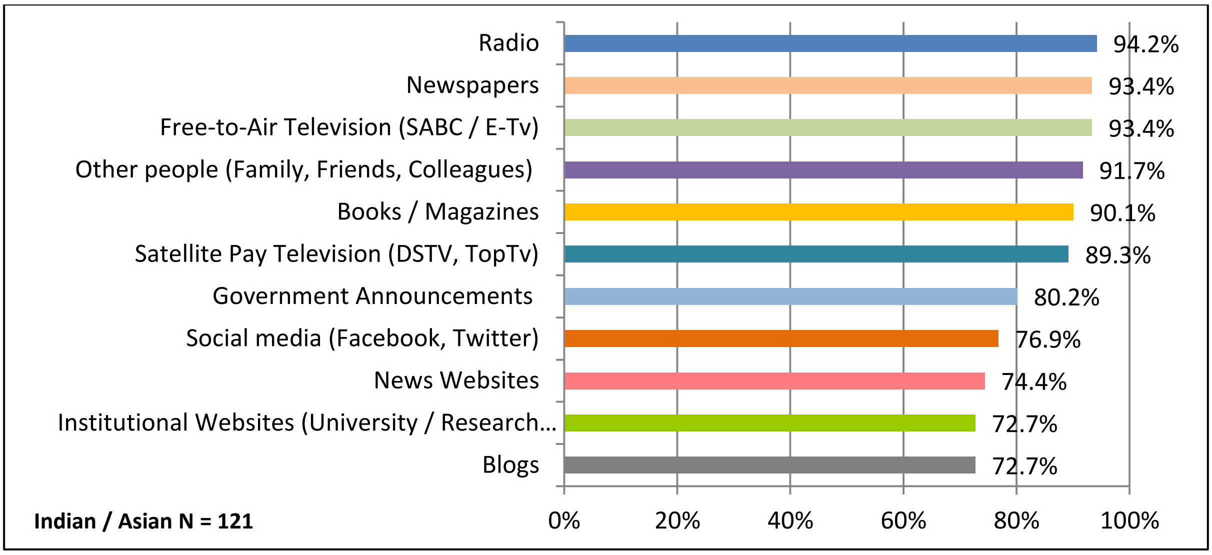


Chart 9.10: Highest ranked science information sources: Indian / Asian subsample

Similar to the black sub-sample, Indian / Asian respondents ranked social media as the 8th most frequent source of scientific information (76.9%), which was followed by decreasing proportional selection for all other online information sources.

Respondents within the coloured sub-sample similarly ranked *radio* (81.3%) as the most frequently accessed science information source. This was again followed by *free-to-air TV* (80.2%) *newspapers* (78.6%); and *other people* (77.9%).

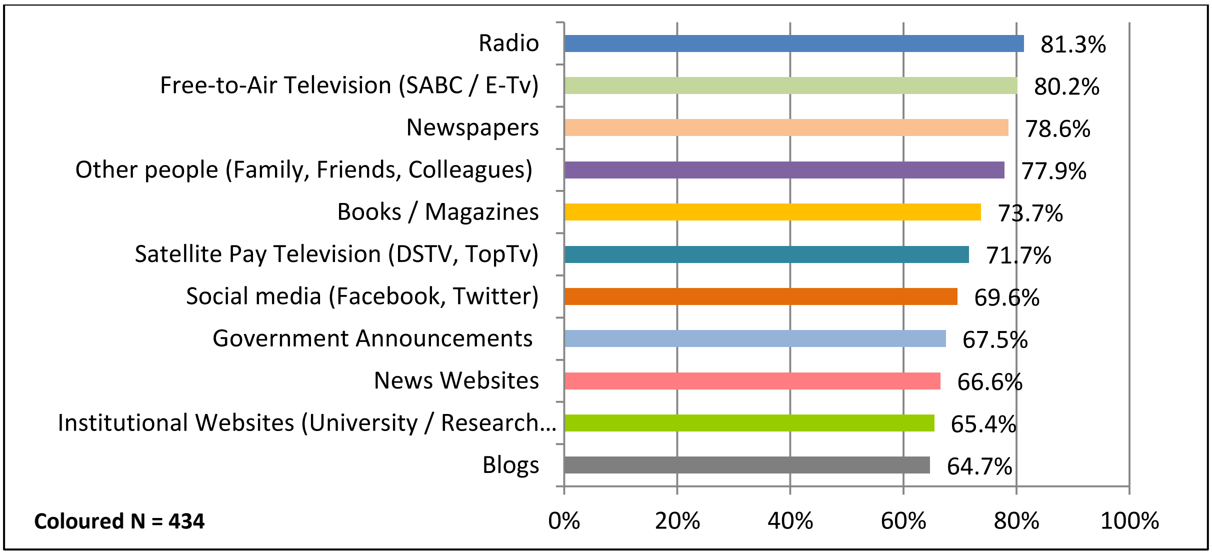


Chart 9.11: Highest ranked science information sources: coloured subsample

As within the other race classifications, all online sources of science information were placed within the bottom of the ranking. *Social media* was ranked 7th (69.6%), while *institutional websites* (65.4%) and *blogs* (64.7%) were the lowest ranked information sources among this race-based sub-sample.

Within the four categories of information channels[127] identified earlier, significant variations have been noted across race classifications.

Radio was the overall most frequently selected source of scientific information, achieving a national proportional frequency of 69.4%. Black respondents reported the highest frequency of selections within this item, followed by white respondents. Among coloured and Indian / Asian respondents the selection of radio, despite their relative ranking within these race groups (above) were lower than the recorded national average and those value reported within the black and white classifications (see chart 9.12).

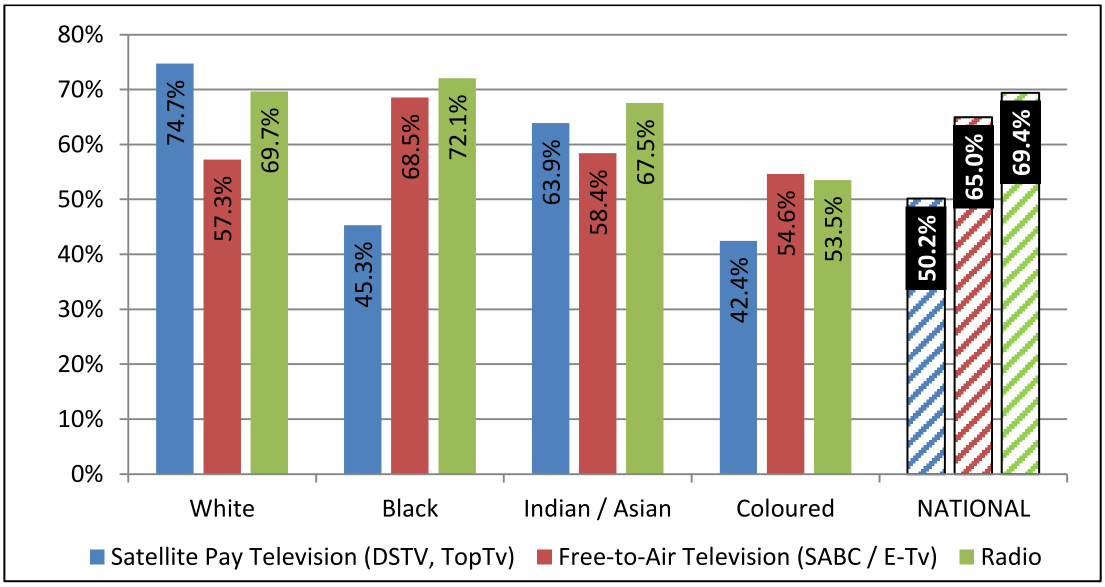


Chart 9.12: Ranking of *Broadcast* science information sources by race

The highest proportion of respondents reporting *free-to-air television* services was within the black (68.5%) sub-sample. Respondents with the Indian / Asian (58.4%); white (57.3%) and coloured (54.6%) sub-samples all reported significantly lower proportions within this category, all of which fell below the level of the national average (65.0%). Not surprisingly, across all race groups, white (74.7%) and Indian / Asian (63.9%) respondents reported the highest frequency of responses within *satellite pay television* item. Among black (45.3%) and coloured (44.2%) sub-samples this proportion was much lower for this questionnaire item, below the recorded national average of 50.2%. This outcome is likely related to the costs associated with *satellite pay television* as well as related to technology penetration and access factors. There may also be important interrelations beyond *income*, to include *employment* and *location* that may further drive this result under *race* classifications.

[127] These include: Broadcast (*Television* and *Radio*); Print (*Books/ Magazines* and *Newspapers*); Human (*Other People* and *Government announcements*) as well as Online (*News Websites*, *Institutional Websites*, *Blogs* and *Social Media*)

Within the print information sources, *newspapers* and *books / magazines* were included. Across all race groups, more respondents selected newspaper as a more frequent source of science information compared to books / magazines.

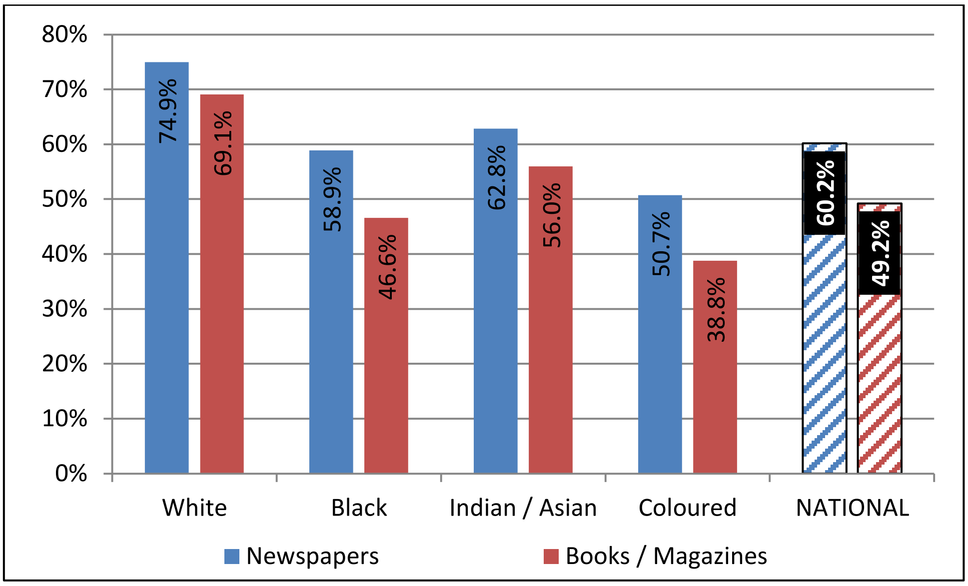


Chart 9.13: Ranking of *Print* science information sources by race

A greater proportion of white respondents selected both *newspapers* (74.9%) and *books / magazines* (69.1%) compared to all other race groups. Similarly among this race group, the variance between the selections of *newspapers* and *books / magazines* was overall the lowest (5.8%). Indian / Asian respondents more often selected *newspapers* (62.8%) over *books / magazines* (56.0%) and presented a correspondingly low variance between these sections (6.9%). Within the black sub-sample, *newspapers* (58.9%) were selected 12.3% more frequently than *books / magazines* (46.6%). A comparable result was achieved by the coloured sub-sample wherein *newspapers* (50.7%) and *books / magazines* (38.8%) differed in selection frequency by 12.0% and were significantly below the frequency recorded in the national average (see chart 9.13).

Among the white (74.9%) as well as the Indian / Asian (64.0%) sub-samples, *human sources* were selected by a proportionally greater number of respondents. Within the white sub-sample in particular, this item was the leading science information sources in terms of the overall ranking, while all other race groups ranked these response options lower. The Indian / Asian sub-sample reported a high response frequency, with 64.0% of this sub-sample selecting *other people* as an important source of science information. Coloured (51.8%) and black (58.3%) respondents reported this selection less frequently than within the white and Indian / Asian sub-sample, at values below the national average (see chart 9.14).

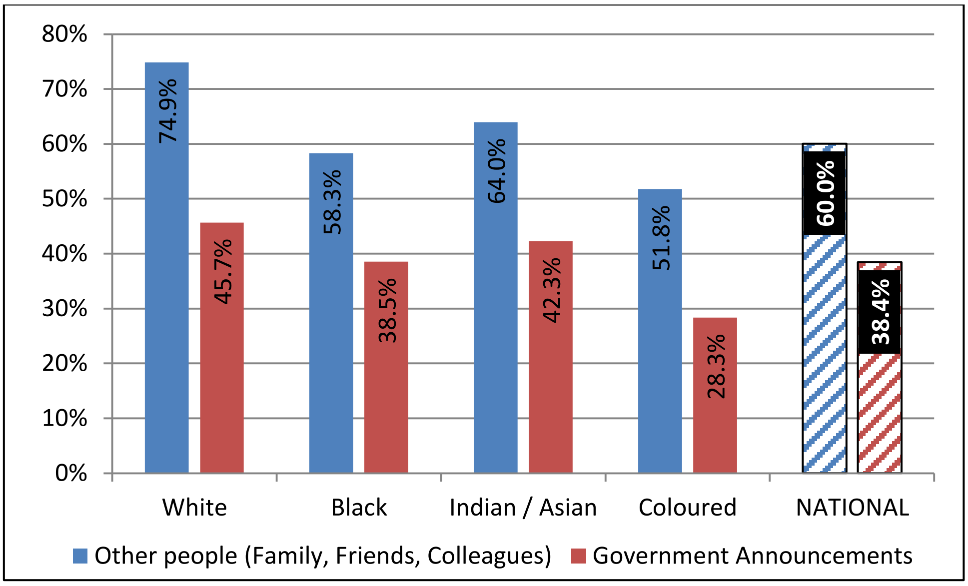


Chart 9.14: Ranking of *Human* science information sources by race

The response option for *government announcements* was generally not reported highly within all race groups. White (45.7%), Indian / Asian (42.3%) and black (38.5%) respondents report this selection above the level of the national average, while within the coloured sub-sample this value (28.3%) was 10.1% below the reported national average for this science information source group.

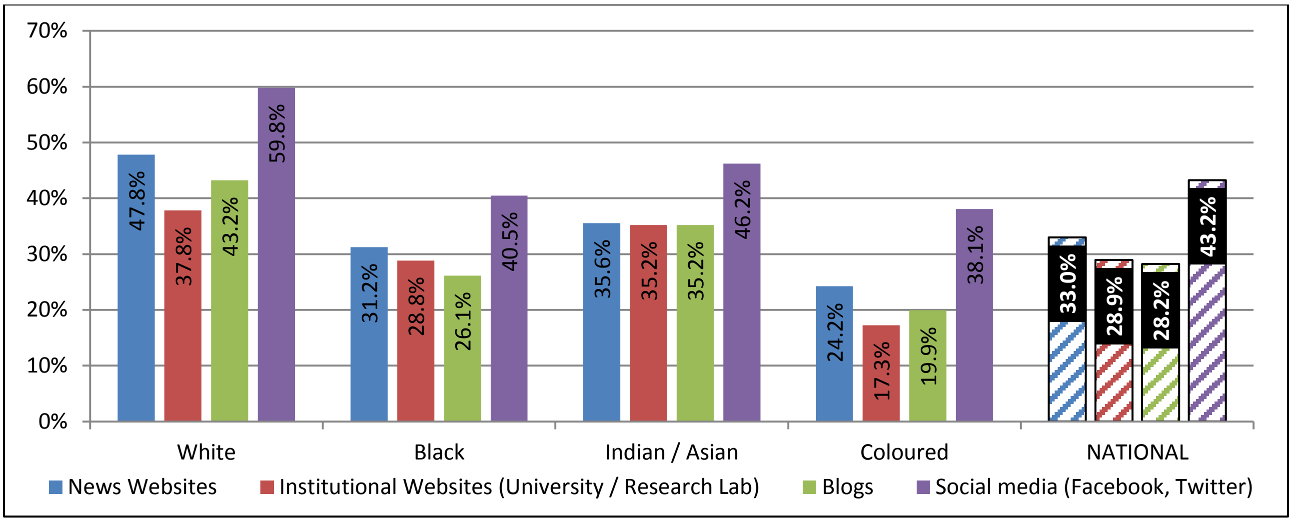


Chart 9.15: Ranking of *Online* science information sources by race

Online sources of science information were generally responded to at lower levels compared to other items within this question set. This is likely related to cost, access and infrastructural availability of internet access in South Africa; however still present an interesting pattern of usage within the sub-groups of online sources.

Within the website sub-group, *news* and *institutional websites* attracted the lower share of response frequency. *News websites* were shown to be a more frequent source of scientific information across all race groups, when compared to *institutional websites* (see chart 9.15). However, *news websites* were selected significantly more frequently within the white sub-sample (47.8%) compared to the levels reported within the other race classifications.

Social media was overall the most frequently selected option within the online information sources. However, white (59.8%) respondents reported this significantly more frequently compared to Indian / Asian (46.2%); black (40.5%) and coloured (38.1%) respondents. The national average for the online item was 43.2%, indicating that both the black and coloured sub-samples report this information source less frequently, than the national average for this sample.

<u>SCIENCE INFORMATION SOURCES BY GENDER</u>

The *gender* variable did not demonstrate a statistically significant association within the respondent selection of science information sources (X^2=4.774, $p > 0.05$). Despite this, at the item level, *radio* (X^2=8.442, $p < 0.001$) and *books / magazines* (X^2=14.654, $p < 0.01$) yielded statistically significant association. Male respondents provided a proportionally lower *SUM frequently* response (47.1% - *21.1%), compared to female respondents (48.5% - *22.1%). Respondents within the male sub-sample were more inclined to select the *least frequently* response option (52.9%) compared to female respondents (51.5%).

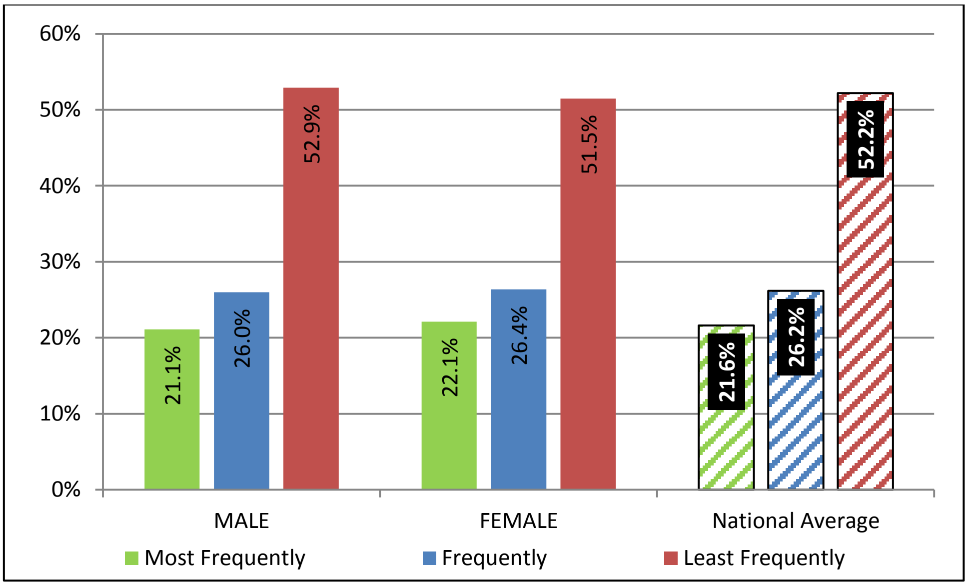


Chart 9.16: Average response by gender group: *science information sources*

Both male (69.9%) and female (69.0%) respondents presented the highest *SUM frequently* proportion within the questionnaire item for *radio*. The second most frequent selection, among both males (64.0%) and females (65.9%) was for the item *free-to-air television*. Males and females differed in their selection frequency related to *newspapers* and *other people*. Males selected newspapers more frequently (60.5%), while females (61.0%) reflected a higher *SUM frequently* proportion within the *other people* item. Males and females did differ in their selection of *blogs*, where females selected this item least frequently (28.3%), and male's selected *institutional websites* (27.8%) as the least frequent science information source.

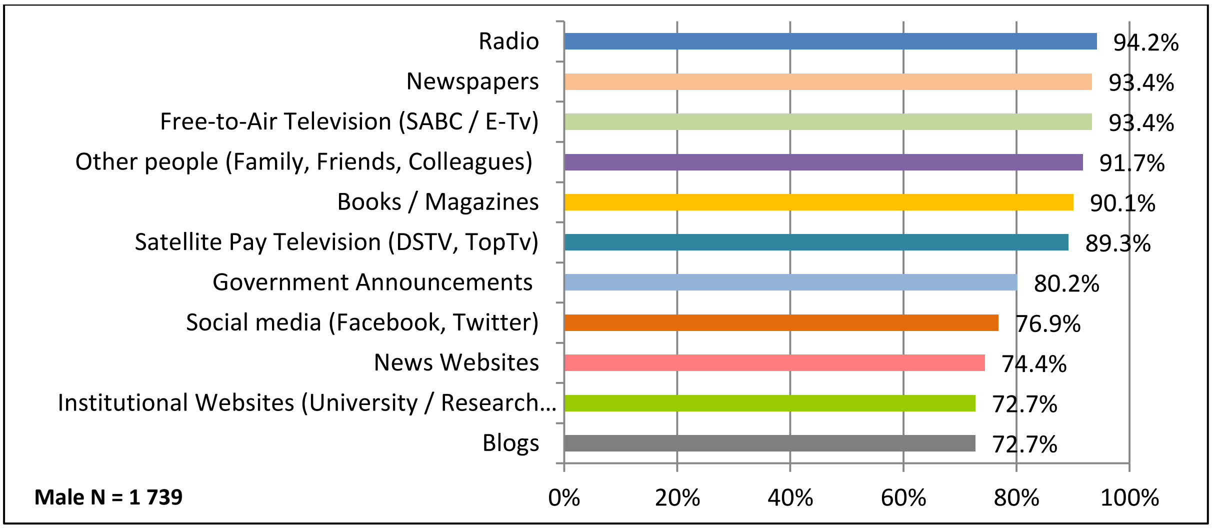


Chart 9.17: Highest ranked science information sources: male sub-sample

Male and female respondents did not differ in their overall ranking of the most frequently selected sources of scientific information. *Radio*; *newspapers*; *free-to-air TV* and *other people* were the highest ranked among the 11 questionnaire options for both gender groups (see chart 9.17 and chart 9.18).

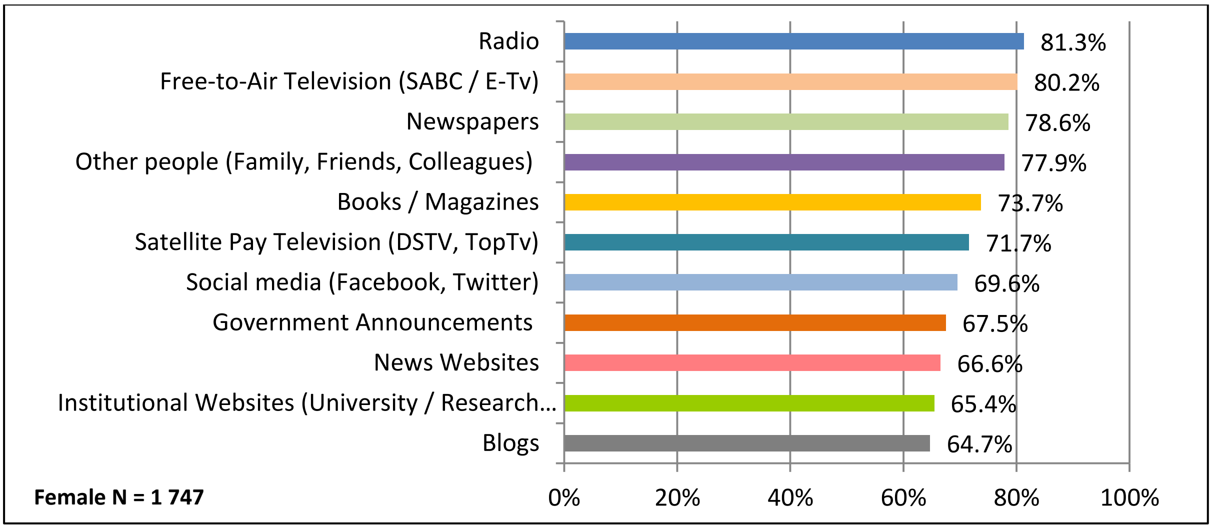


Chart 9.18: Highest ranked science information sources: female subsample

All online based information sources received similarly low rankings for both males and females, with blogs being ranked as the least frequently accessed science information source. The variations in the overall proportions between males and females are as a result of females (27.5%) making a greater number of *don't know* selections across the 11 items, compared to the male (25.5%) sub-sample.

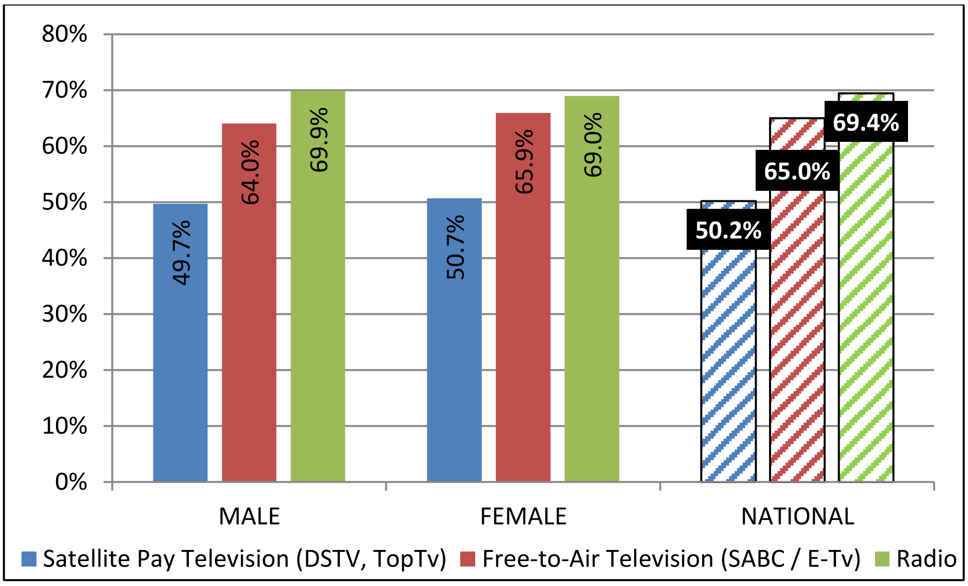


Chart 9.19: Ranking of *Broadcast* science information sources by gender group

Within the four categories of information channels there were no large variations between gender groups and their *SUM frequently* selections for each of the information channels.

Female respondents showed higher response proportions within *satellite TV* and *free-to-air TV*, however slightly lower proportions within their selections of the *radio* item. The variation on the *radio* item, between males (69.9%) and females (69.0%), though very small, was shown to be statistically significant at the item level.

Bothe males and females made greater selections within the *newspaper* option compared to the *books / magazines* source of science information (see chart 9.20). Male respondents presented a proportionally higher response (60.5%) to the *newspaper* compared to members of the female sub-sample (59.9%), though this was not found to be a statistically significant variance. However, significantly more females (52.9%) than males (45.5%) reported *books / magazines* as a frequent source of science information (X^2=14.654, p < 0.01).

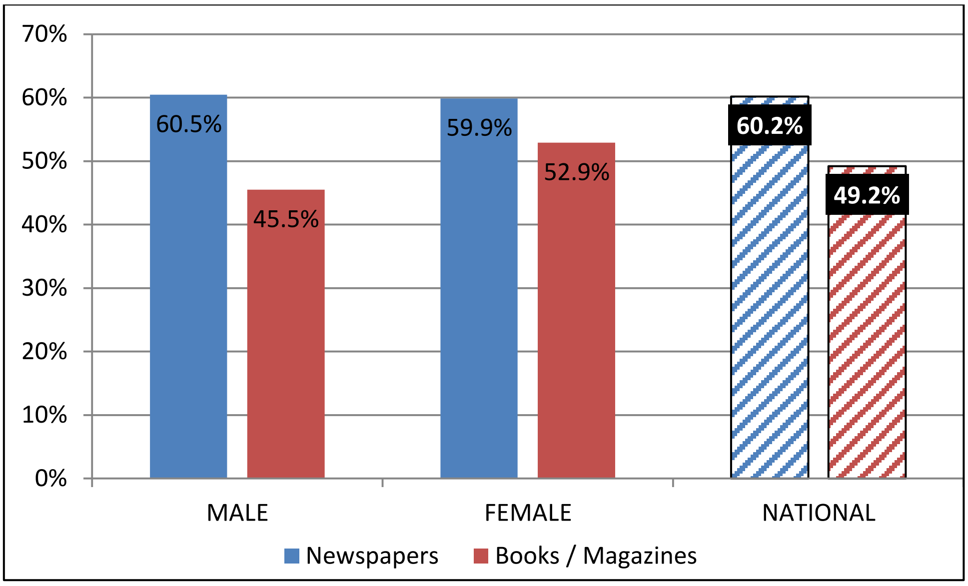


Chart 9.20: Ranking of *Print* science information sources by gender group

Human information sources similarly did not highlight any statistically significant gendered variations. Female respondents reported *other people* more frequently than male respondents. While similarly, females reported a higher proportion of *SUM frequently* responses within the *government announcements* science information source category (see chart 9.21).

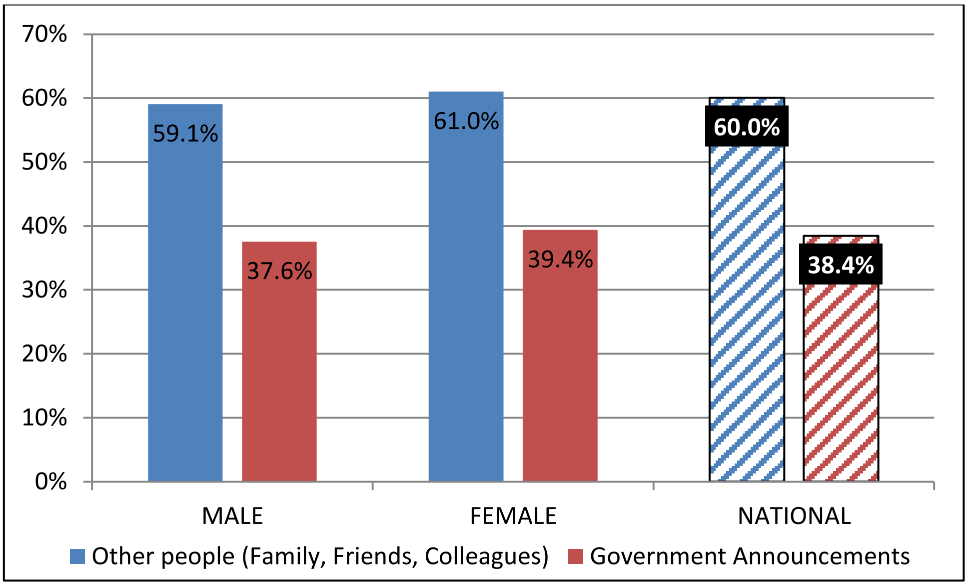


Chart 9.21: Ranking of *Human* science information sources by gender group

Online sources of scientific information were infrequently selected by both male and female respondents. Within the website sub-category, a greater proportion of males (33.7%) selected a *SUM frequently* response within the *news website* option compared to female (32.2%) respondents. Conversely, a greater proportion of females (30.1%) report *institutional websites* as a source of science information compared to the male (27.8%) sub-sample (see chart 9.22). However these results were not found to be statistically significant.

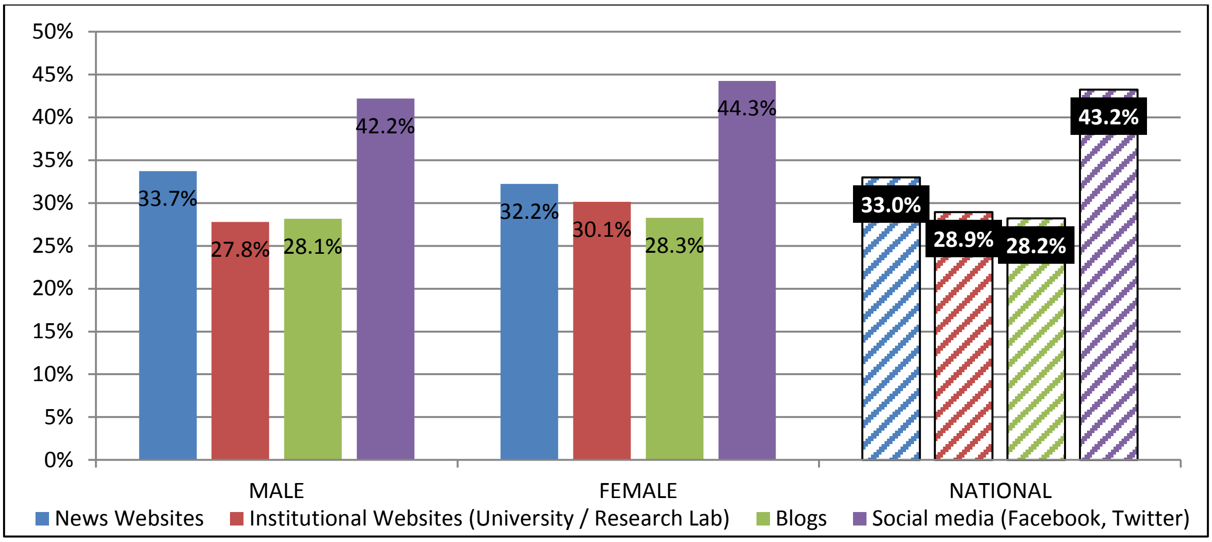


Chart 9.22: Ranking of *Online* science information sources by gender group

The *social media* sub-group achieved the greatest proportion of response from both males and females (see chart 9.22). Within both gender groups, *blogs* achieved the lowest proportion of *SUM frequently* responses and consequently was the least common source of science information for these sub-samples.

SCIENCE INFORMATION SOURCES BY GEOGRAPHIC LOCATION

Respondent geographic location is significantly associated with response selections within the sources of science information question set (X^2=71.268, p < 0.001). Across all items, urban (51.8% - *23.3%) respondents reported a significantly higher response proportion within the *SUM frequently* categories, compared to rural respondents (39.0% - *17.9%). Rural respondents were more inclined to select a *least frequently* response compared urban respondents (see chart 9.23).

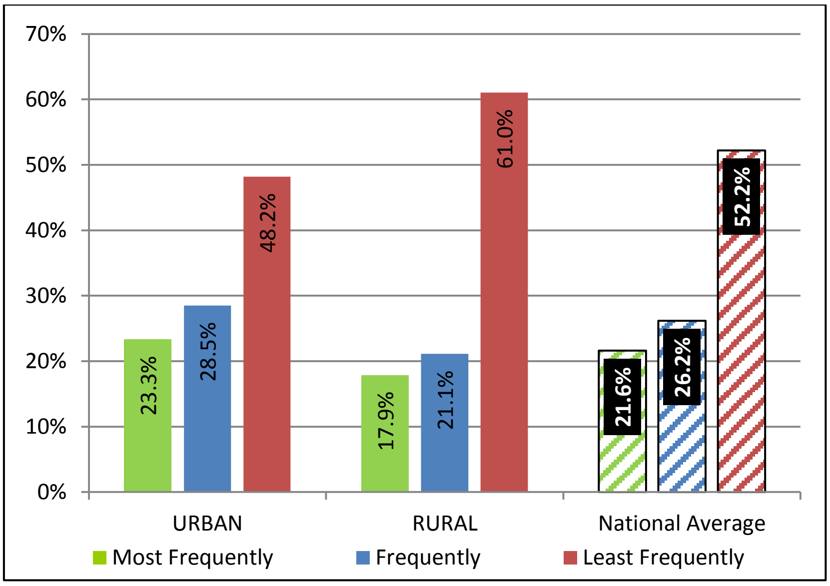


Chart 9.23: Average response by location group: *science information sources*

Among both the rural (65.3% - *41.0%) and urban (71.4% - *38.8%) sub-samples, *radio* was most often selected as the information source within the *most frequently* and *occasionally* response options (*SUM frequently*). Rural respondents selected a higher proportion of response on *radio* within the *most frequently* response option compared to urban respondents; however this was not entirely unexpected. Both sub-samples selected *free-to-air TV* as the second most frequent science information source (rural: 59.4% - *36.8%; urban: 67.6% - *38.1%). The next four most selected response options appear within both rural and urban sub-samples, however, in slightly differing proportions (see chart 9.24). The category for *other people* was selected more frequently within the urban sub-sample, followed by *newspapers*; while this order was reversed within the rural sub-sample. Likewise, *books / magazines* was more frequently selected by rural respondents, followed by *satellite pay TV;* while this response order was reversed within the results for the urban sub-sample.

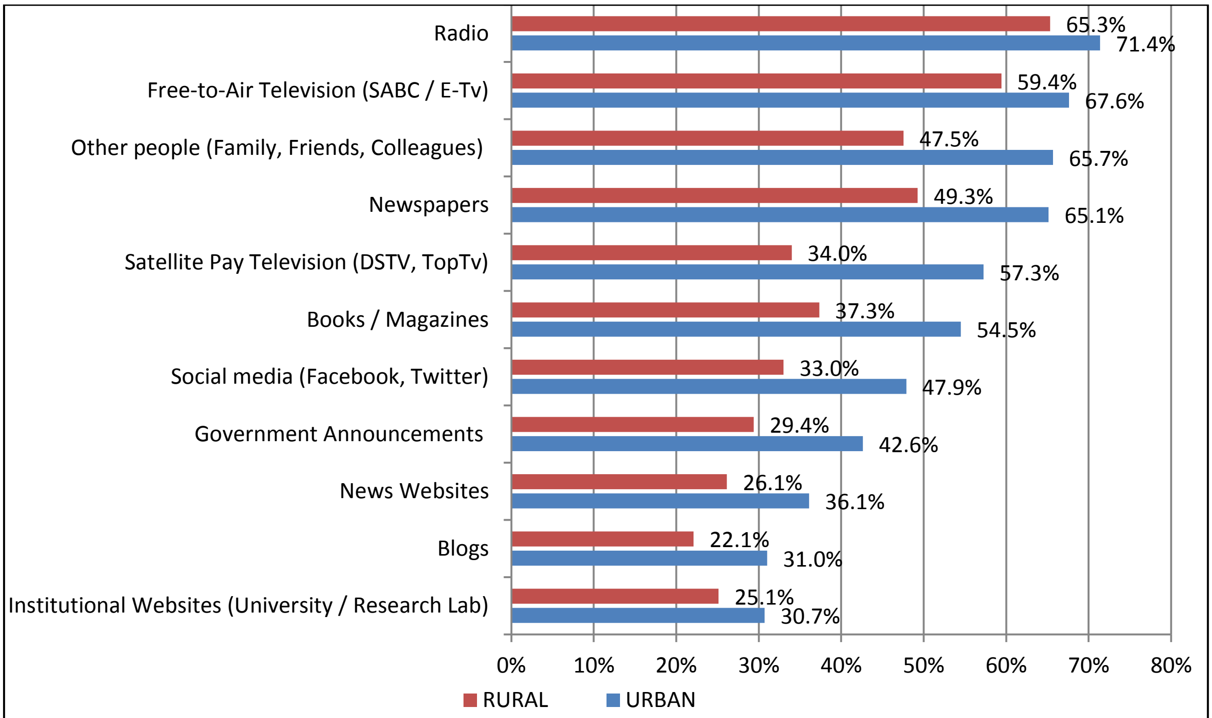


Chart 9.4: *SUM frequently* item response selection: sources of science information

The options reporting the lowest *SUM frequently* response was *institutional websites* and *blogs*, though rural respondents reported *blogs* less frequently compared to urban respondents.

Based on the above selections (excluding *don't know* responses), the ranking of information sources for both urban and rural sub-populations are presented within charts 9.25 and 9.26 below.

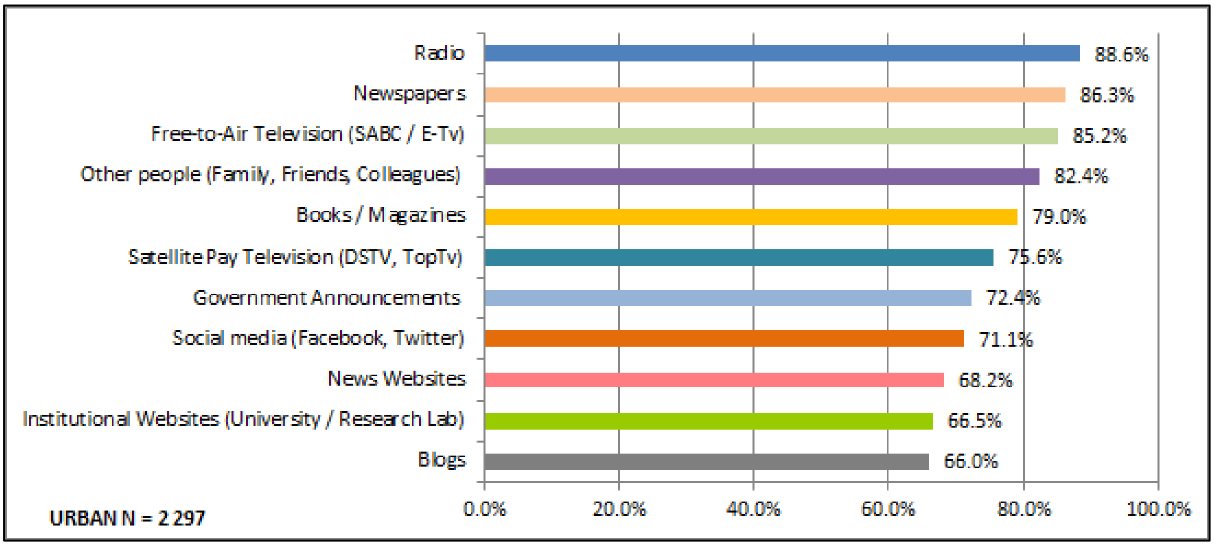


Chart 9.25: Highest ranked science information sources: urban sub-sample

Within rural and urban sub-samples, despite variations in response selections, discussed above, *radio* was ranked as the most frequently accessed science information source. Among the rural sample the next three items with the highest ranking order were: *free-to-air television* (77.3%); *newspapers* (76.1%) and *other people* (71.8%). This ranking order was reversed for *newspapers* and *free-to-air television* among the urban sample; however *other people* remained in 4th ranking order for both sub-samples.

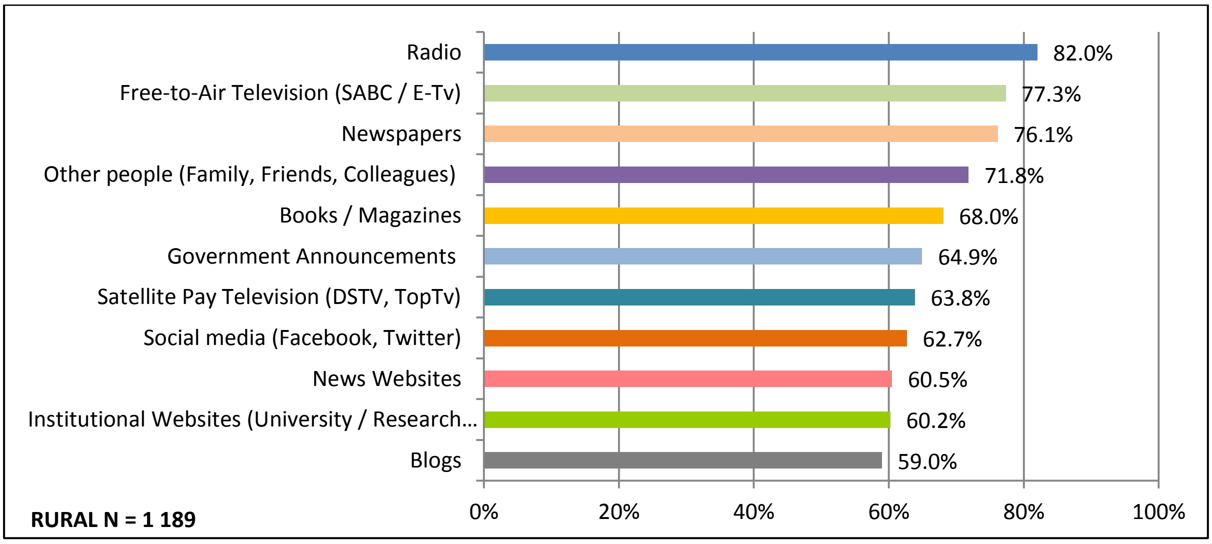


Chart 9.26: Highest ranked science information sources: rural sub-sample

Respondents within the rural sub-sample ranked *government announcements* higher than members of the urban sub-sample. The *online* sources of scientific information were ranked lowest within both urban and rural sub-samples, and the order of ranking was consistent within both sub-samples, despite proportional variations. The relatively lower proportional response for the rural sub-sample within *satellite pay TV* and the various *online* information sources may be as a result of technology penetration, higher costs associated with these services as well as access and infrastructural factors within the rural setting.

The four categories of information channels presented some significant variations within the response across geographic location classifications.

Radio was the most widely accessed science information source among both urban and rural respondents. However, significantly higher proportions of urban (63.2%) respondents reported *radio* as a science information source, compared to rural (53.6%) respondents. Similarly, *free-to-air TV* attained a higher *SUM frequently* response among urban respondents compared to rural respondents (see chart 9.27).

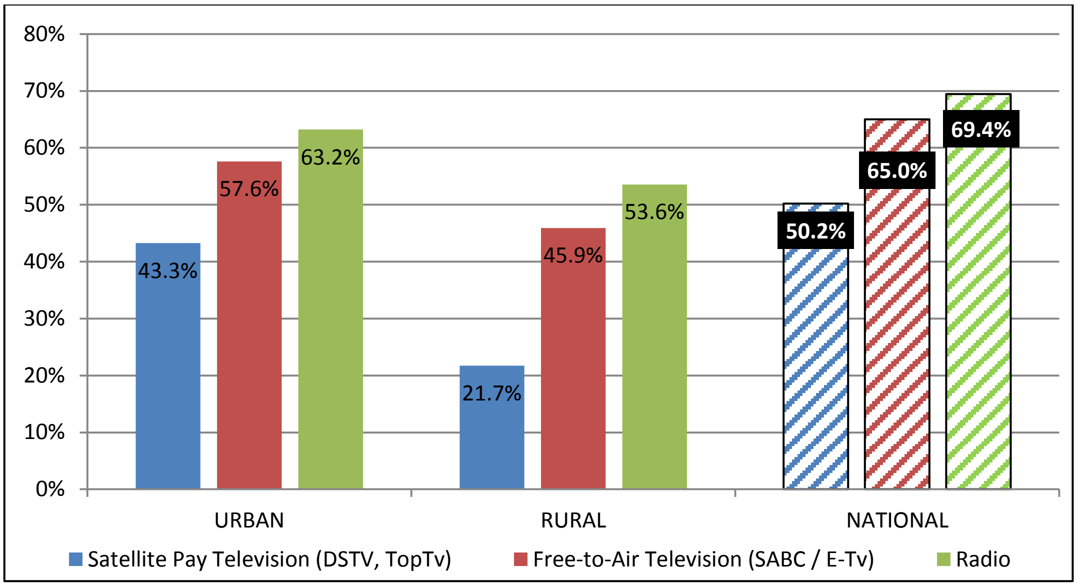


Chart 9.27: Ranking of *Broadcast* science information sources by geographic location group

The selections for *satellite pay TV* were higher among urban respondents (43.3%), compared to rural respondents (21.7%), however this was not unexpected and relates to the earlier discussed accessibility and cost considerations.

It remains important to note that the above result is not a holistic reflection of media pattern usage between rural and urban sub-samples, however is reflective only of these channels as most frequent *sources of science information* among each location group classification.

Reviewing the proportionality of response between urban and rural sub-samples, it becomes immediately apparent that a greater proportion or urban respondents access science information via one of the 11 information channels, when compared to the proportions among the rural subsample.

Print based information sources reflected a similar pattern of increased response within the urban sub-sample compared to rural respondents. Within both rural and urban sub-samples, *newspapers* received a higher proportional response compared to *books / magazines*. Significantly greater proportions of urban respondents selected *newspapers* as a science information source (*most frequently* or *occasionally*), compared to rural respondents.

A similar pattern is observed within responses for *books / magazines,* where rural respondents report 17.7% less frequently into this option (see chart 9.28)

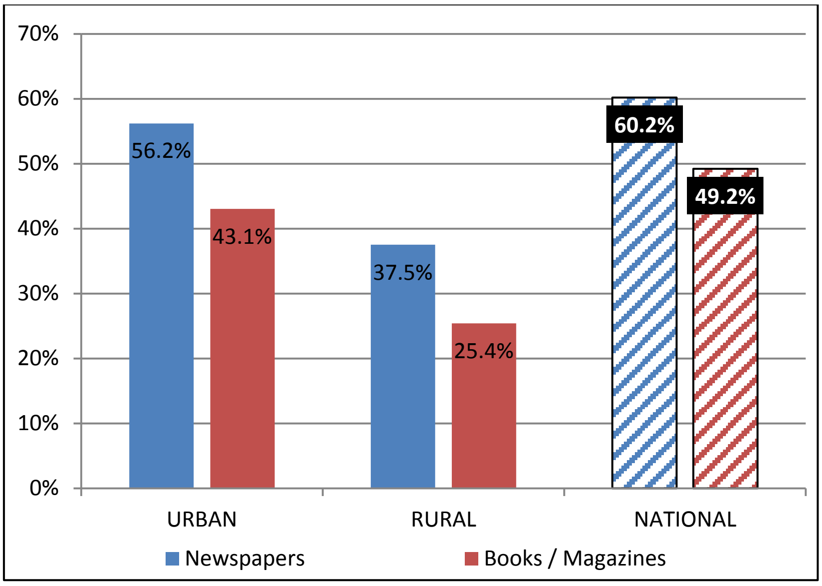


Chart 9.28: Ranking of *Print* science information sources by geographic location group

Respondents within the urban sub-sample selected a greater proportion of *SUM frequently* responses within the *human* information sources categories. Selections among the urban subs-ample were significantly higher for both these questionnaire items, compared to the selections within the rural sub-sample. However among both these location groups, the proportion of responses were lower than that recorded within the overall national response (see chart 9.29).

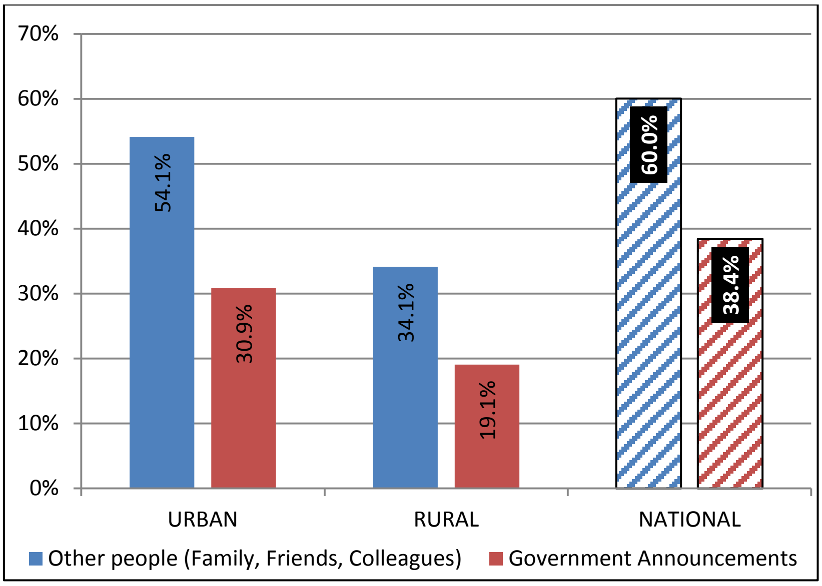


Chart 9.29: Ranking of *Human* science information sources by geographic location group

Online sources of scientific information were ranked similarly low by both urban and rural respondents. However despite this urban respondents provided a significantly higher proportion of responses within all four online information source categories (see chart 9.30).

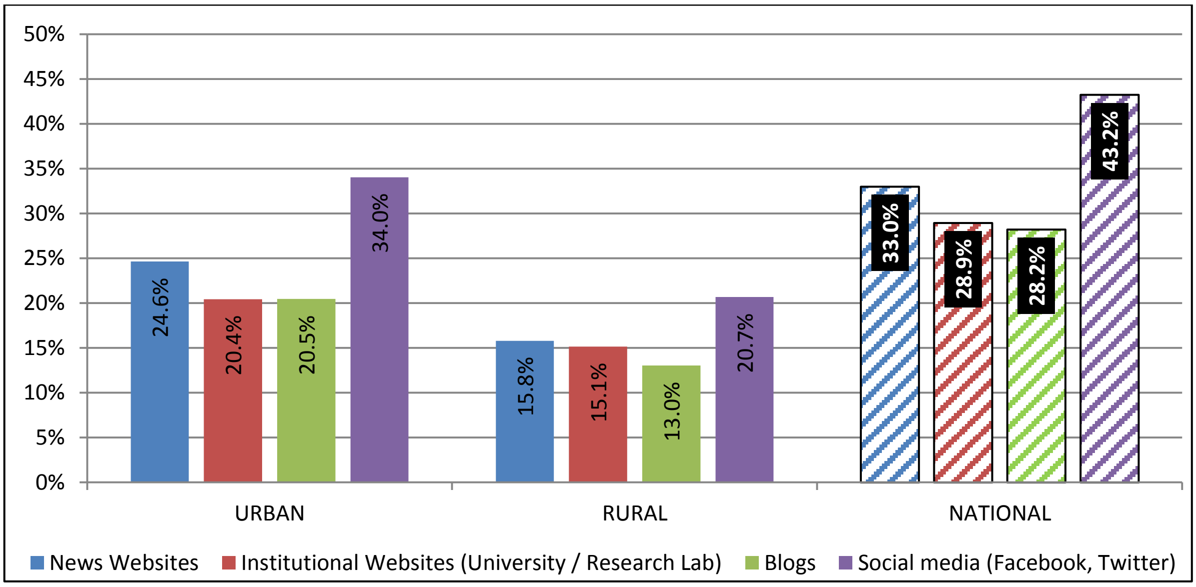


Chart 9.30: Ranking of *Online* science information sources by geographic location group

Within the websites sub-group, the urban sub-sample reported higher proportions within *news websites* compared to *institutional websites*, while there was little variation in the proportionality of these response options for the rural sub-sample. Within the social media sub-group, urban respondents reported a greater proportion of responses within *social network* information sources, compared to selections within the *blog* option. Urban populations reported within these categories more frequently than the rural sub-sample.

SCIENCE INFORMATION SOURCES BY EDUCATIONAL ATTAINMENT

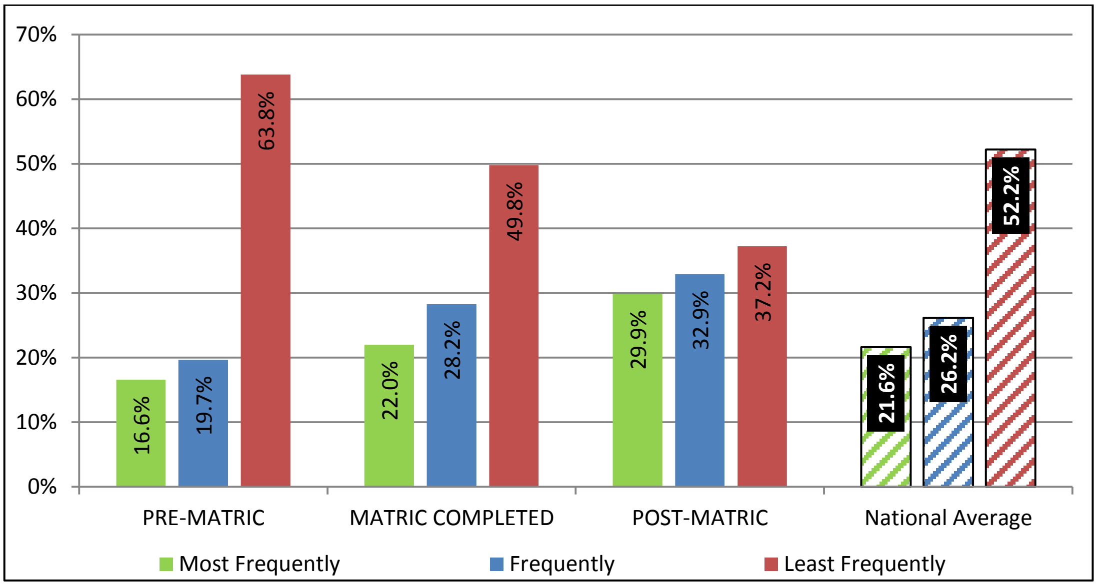


Chart 9.31: Average response by educational attainment group: *science information sources*

Within the national sample, *educational attainment* levels were significantly associated with reported frequency of accessing science information across the 11 questionnaire items (X^2=283.615, p < 0.001). Within the average response per education group classification it is clear that a significantly higher proportion of responses were recorded as educational level increases. The *SUM frequently* responses recorded within the post-matric group was significantly higher (62.8% - *29.9%) than that recorded within the matric completed (50.2% - *22.0%) or the pre-matric (36.2% - *16.6%) educational classicisation (see chart 9.31). Similarly, a higher proportion of *least frequently* response is reported within the lower educational attainment group (63.8%) when compared to those within the post-matric group (37.2%).

Among both the *pre-matric* and *matric completed* groups the largest response proportions were recorded within the *radio* and *free-to-air television* items. Within the post-matric sub-sample, *radio* was similarly the most frequently selected information source; however this was followed by a greater proportional response within the *satellite pay TV* items (see chart 9.32).

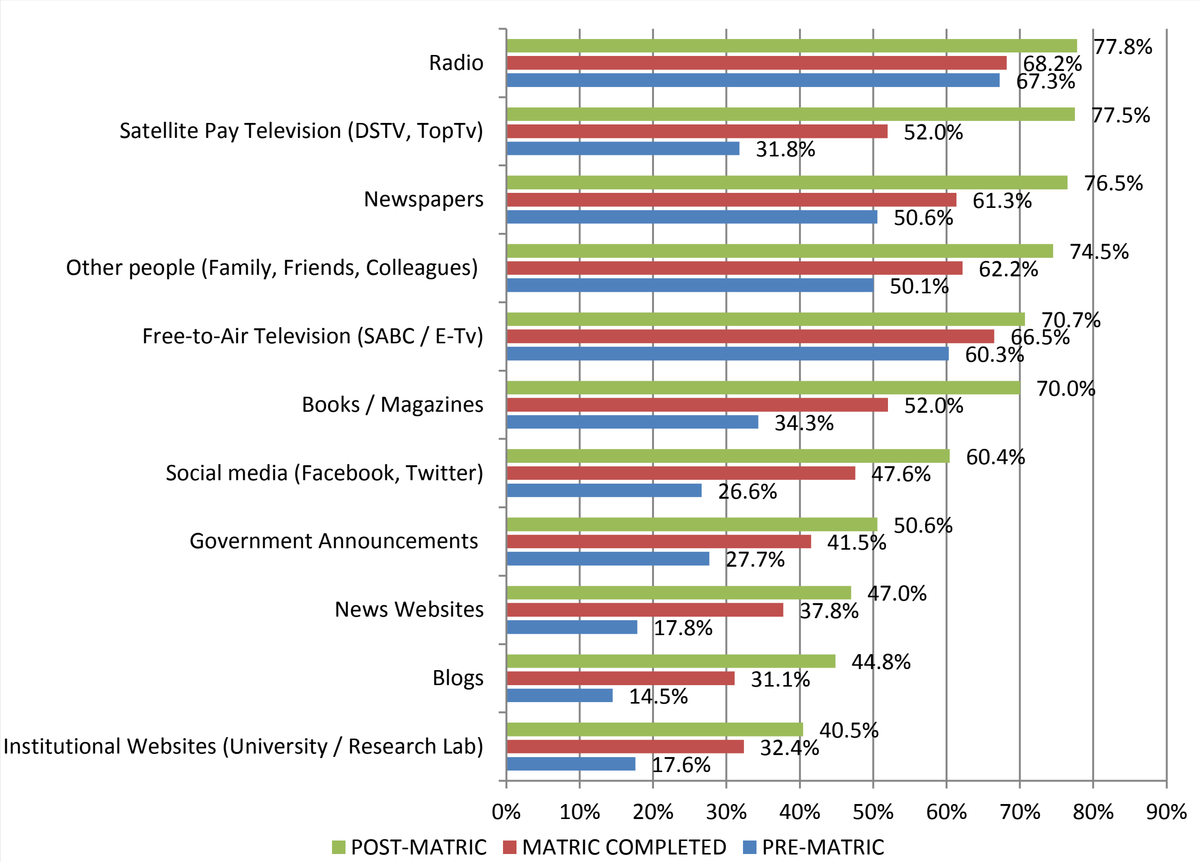


Chart 9.32: *SUM frequently* item response selection: sources of science information question set

Within all educational attainment groupings the questionnaire items for *news websites*; *blogs* and *institutional websites* achieved the lowest proportional *SUM frequently* response. Though despite this, the post-matric sub-sample selected *blogs* more frequently than institutional websites when compared to respondents within the matric completed and pre-matric groups.

The combination of all valid responses within the question set, allowed for the development of a ranking order of science information sources by *educational attainment* group.

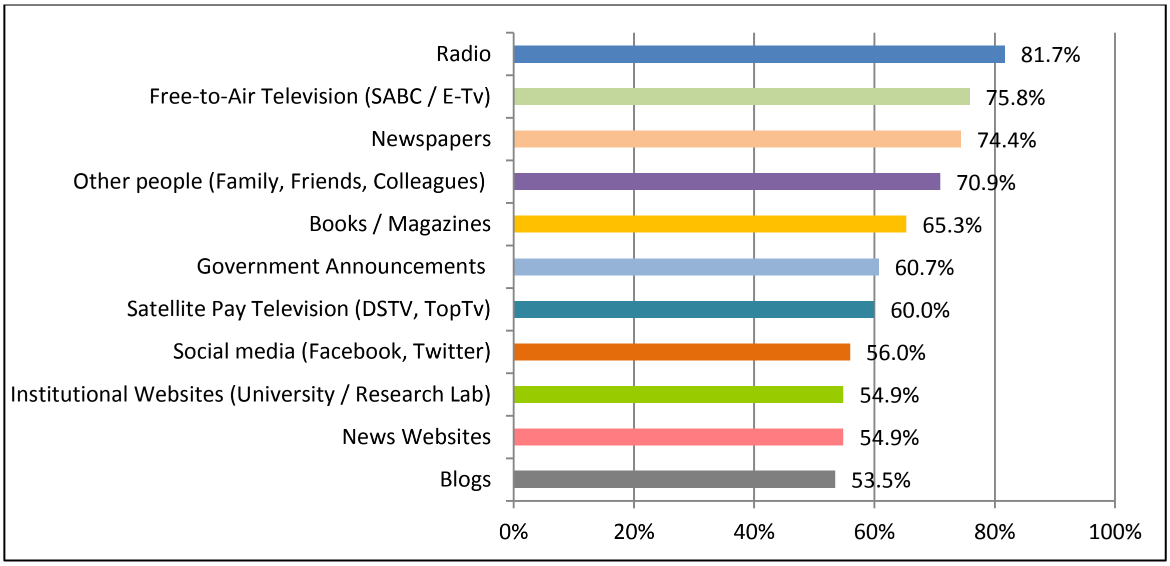


Chart 9.33: Highest ranked science information sources: pre-matric sub-sample

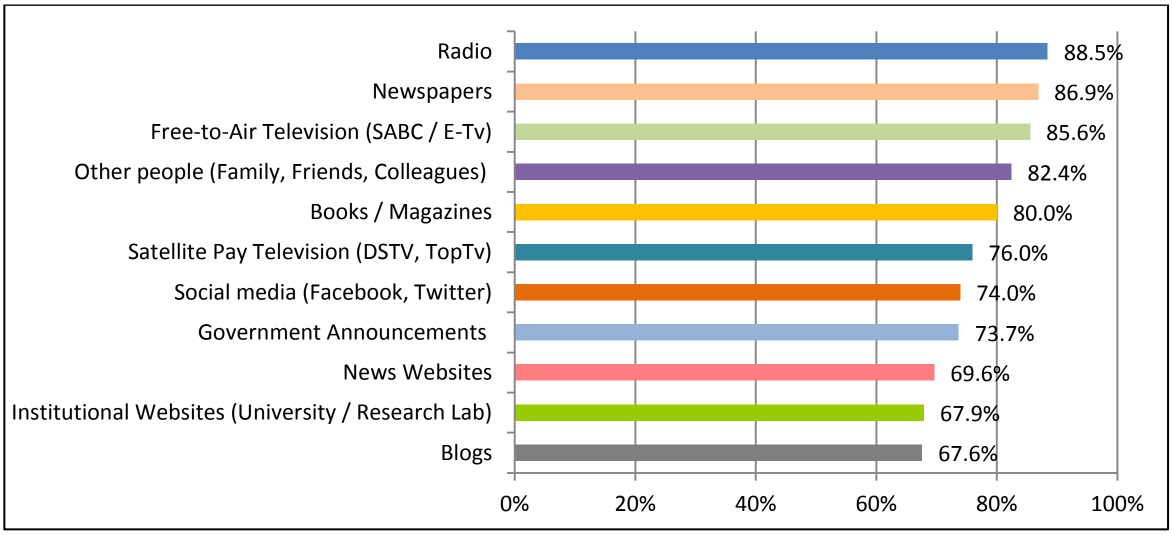


Chart 9.34: Highest ranked science information sources: matric completed sub-sample

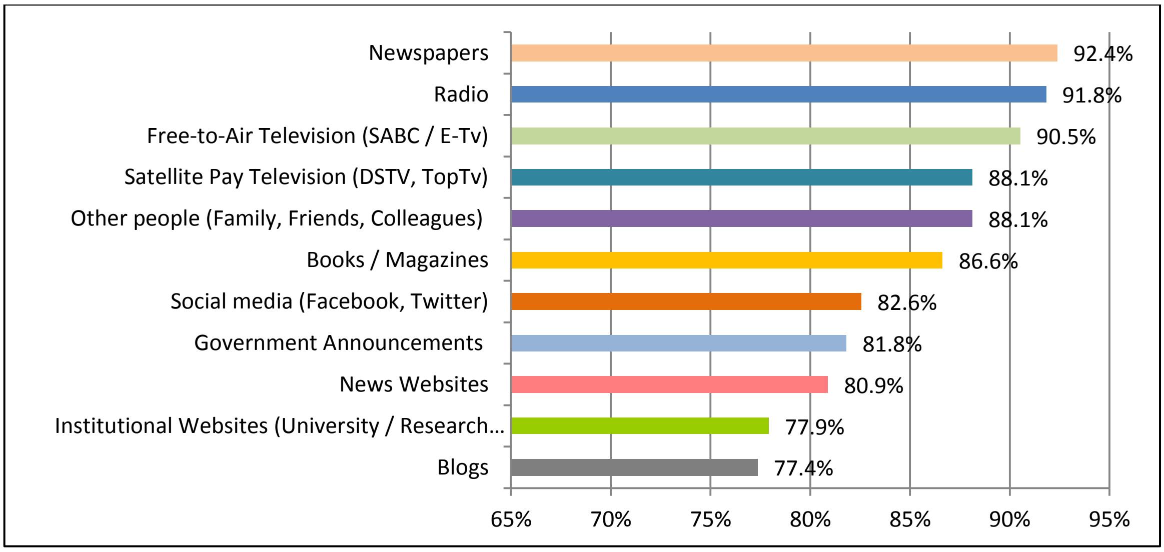


Chart 9.35: Highest ranked science information sources: post-matric sub-sample

The pre-matric and matric completed educational attainment groups both ranked *radio* as the most frequently accessed science information source, while respondents within the post-matric sub-sample rated *newspapers* above *radio*. Those in the matric completed group ranked *newspapers* as second most frequent source of science information. Respondents within the pre-matric subsample placed *free-to-air television* in this position (see chart 9.33-9.35 above). Respondents with pre-matric and matric completed educational attainment ranked *television*, more frequently within their response selections. This however may be related to access factors and associated costs considerations, as income has previously been shown to be significantly related to educational attainment classifications within this sample (X^2=597.702, $p < 0.001$).

Government announcements were rated significantly higher within the pre-matric education group, compared to those with completed matric and post-matric qualifications, despite the lower proportions reported within these sub-samples (see chart 9.33). All educational attainment groups reported similarly low rankings within *online* science information sources, with *blogs* receiving the lowest proportional response.

Viewing the results of science information sources within educational attainment categories, the information channel categories are presented below. There remains a clear pattern of increased *SUM frequency* response across all *broadcast* categories of science information sources with increased educational attainment. Across all educational attainment groups, *radio* was the most frequently reported source of science information.

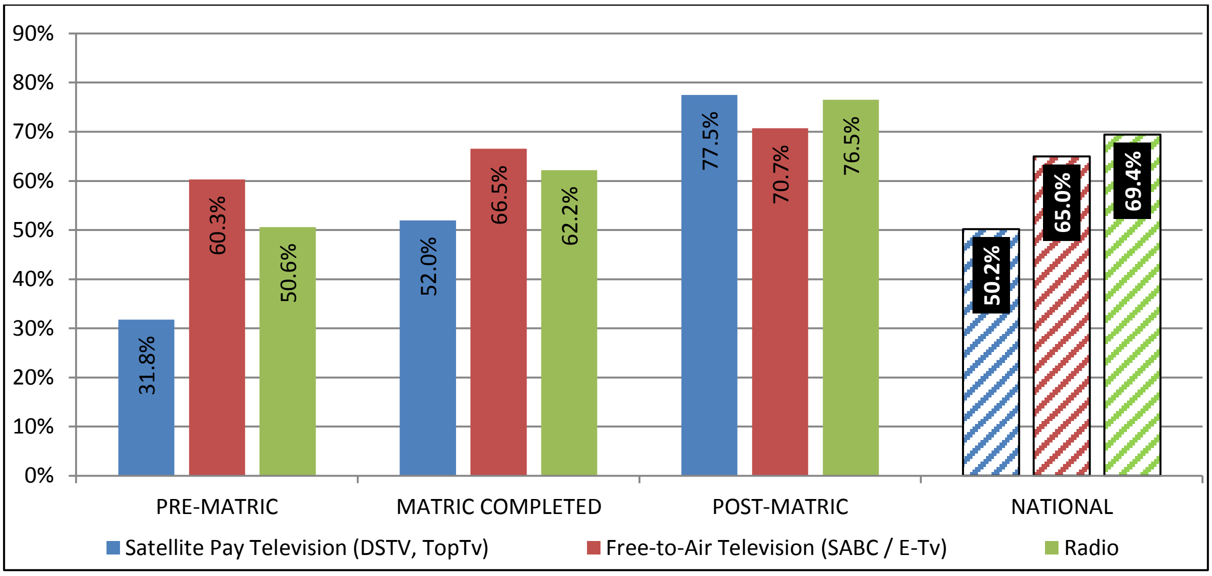


Chart 9.36: Ranking of *Broadcast* science information sources by educational attainment group

The proportional response across educational attainment groups for the *free-to-air TV* item varied by 10% between the pre-matric and post matric groups, indicating a similar level of importance of this information channel among respondents. By contrast, the selections for *satellite pay TV* varied significantly by educational attainment group, with 77.5% of post-matric respondents indicating this while within the pre-matric group the proportional selections was 31.8%. Possible reasons for this disparity may have little to do with the actual information channel preference but more so to do within cost and access factors discussed previously.

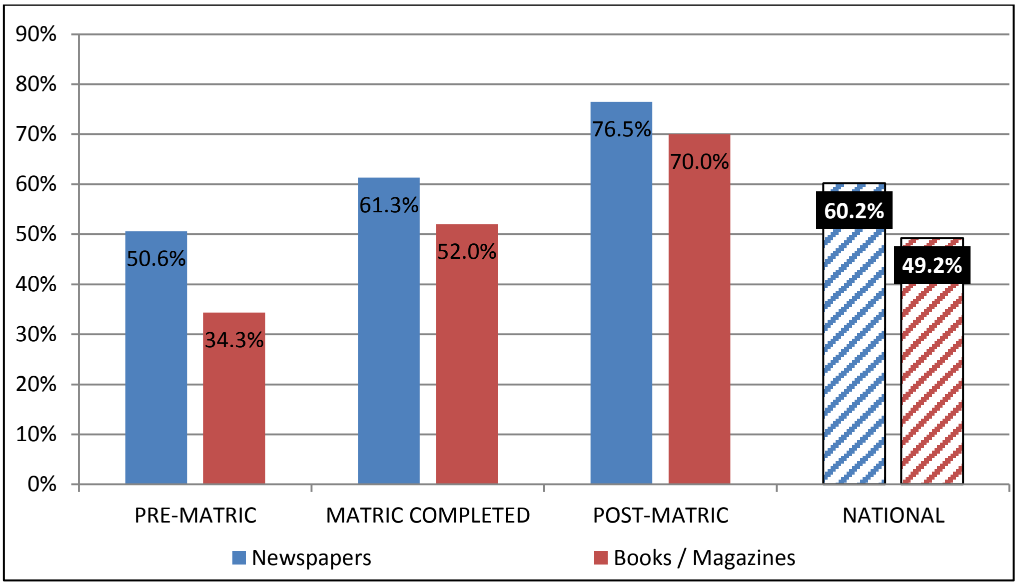


Chart 9.37: Ranking of *Print* science information sources by educational attainment group

Newspapers were selected more frequently than *books / magazines* across all educational attainment groups. Within selections for *books / magazines* and *newspapers*, there is a higher response frequency within the post-matric grouping when compared to those with a completed matric or pre-matric education (see chart 9.37). Within the post-matric group, the variance between the proportion of respondents selecting *books / magazines* and those selecting *newspapers* is lower when compared to the variance in selections within the other educational attainment groups. The higher proportions for respondents within the post-matric educational is not unexpected as a result of these individuals having to seek scientific information more frequently due employment or post schooling educational requirements, when compared to pre-matric or matric completed educational categories.

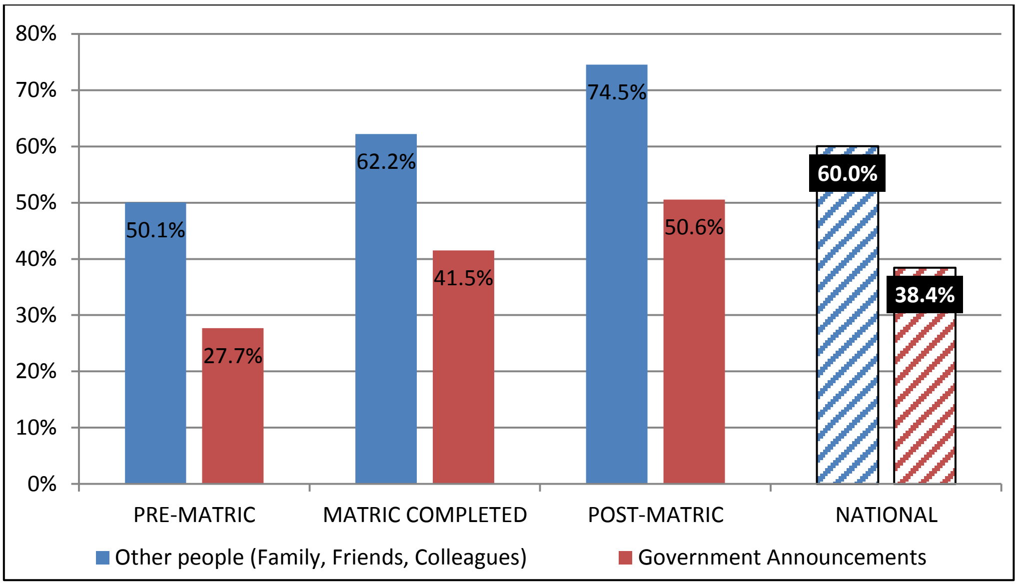


Chart 9.38: Ranking of *Human* science information sources by educational attainment group

The response category for *other people* was frequently selected by all respondents, irrespective of educational attainment group. However reviewing the responses within the *SUM frequently*[128] response, it is apparent that respondents with post-matric educational attainment selected this information source more often than respondents within the other sub-samples. The response recorded within the post-matric group, was 14.5% above the level of the national average for this response option. However, despite this, a higher response was recorded among all educational attainment groups for *other* people, when compared to the response recorded within the *government announcements* item. As with the *other people* response option, respondents with the matric completed and post-matric sub-samples selected the government announcements option above the level recorded for the national average while those with pre-matric responded below this level (see chart 9.38).

The expectation that respondents with higher educational attainment would more frequently report accessing scientific material *online* is supported by the data presented in chart 9.39 below.

[128] Sum of most frequently and occasionally response

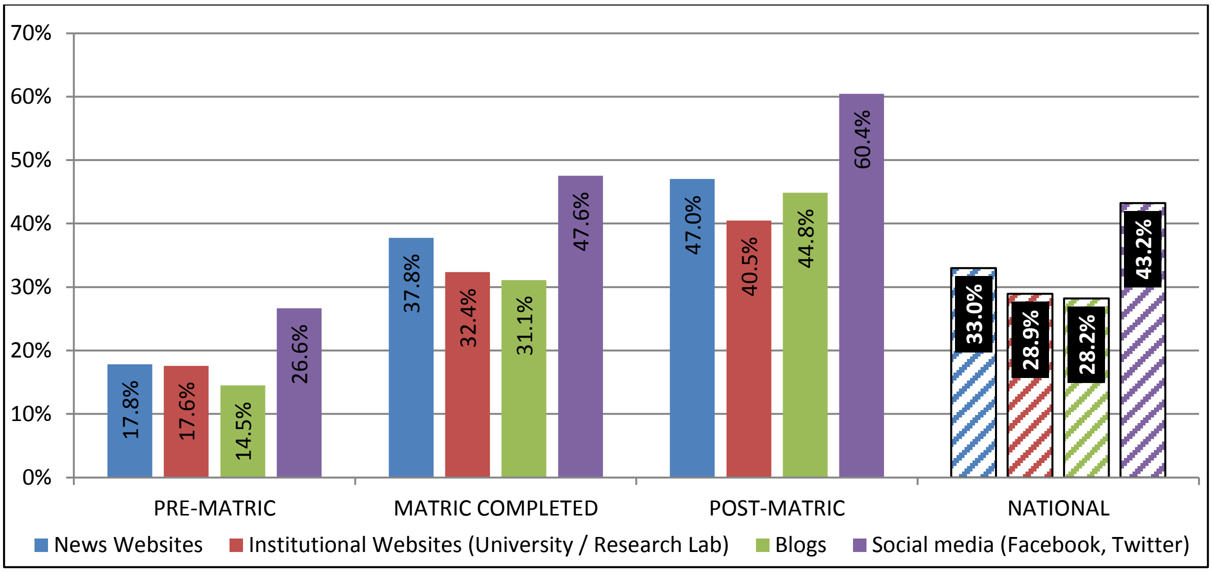


Chart 9.39: Ranking of *Online* science information sources by educational attainment group

Within the pre-matric group, both news websites and institutional websites received a similar proportional response of *SUM frequently* selections. *Blogs* received a particularly low response within this group as a source of science information; however, *social network websites* did receive the highest proportional response among respondents with pre-matric education. Respondents within the matric completed sub-sample provided more frequent selections of *online* information sources, compared to those with pre-matric education. Similarly, this sub-sample showed more *SUM frequently* selections within *news websites*, compared to *institutional websites* as an information source. However, the response for the latter was still higher than the proportion of response under the *blogs* item (see chart 9.39).

Respondents within the post-matric education group selected all *online* information sources more frequently than respondents within the other education sub-samples. *News websites* received a higher proportional response compared to *institutional websites* as a frequently used science information source. Compared to other educational attainment groups, the post-matric sub-sample reported *blogs* as a source of science information more often compared to *institutional websites*. In line with the expectation, this group rated social media more frequently as a source of scientific information, 17.2% above the level recorded within the overall national result. Despite this, all educational attainment groups ranked *online* sources of science information, except *social media*, very low within their respective selections.

Conclusion

Sources of scientific information were assessed using an 11-item question set containing various channels of information. Response within this assessment reveals that overall, South Africans encounter scientific information most frequently via the *radio* (86.3%); followed by *newspapers* (82.8%), *free-to-air television* (82.5%) and through contact with *other people* (78.8%). The media sources least frequently selected as sources of science information were all within the *online* channels. These were ranked as follows: *social media* (68.2%); *news websites* (65.6%); *institutional websites* (64.3%) and *blogs* (63.6%).

It remains important to note that the rankings of information source presented in this chapter relate specifically to channels of *science information* most frequently encountered within the general South African public. This may differ from established media consumption pattern, however in general the results reveal some degree of overlap in this regard.

While all race groups selected *radio*, *newspapers* and *free-to-air television*, overall ranking of information sources did show some variation within race classifications. White respondents indicated that the most frequently accessed source of science information was *other people* (74.9%), followed by *newspapers* and then *radio*. Within the black, Indian / Asian sub-samples, *radio* was the most frequently selected information source, with *newspapers* and *free-to-air television* being the next three most frequent selections. Within these two race classifications, the selection proportions were significantly higher within the Indian / Asian sub-sample compared to the black sub-sample, however the ranking remains the same. Respondents within the coloured race group selected radio most frequently, followed by *free-to-air television* and then *newspapers*.

A similar response pattern emerged within gender groups, where the selections remained within *radio*, *newspapers* and *free-to-air television*. Across all 11 questionnaire items, males provided a higher proportional response in all items, compared to females. This may be indicative of males more frequently accessing scientific information, which relates well to the previously discussed gender variations under *informedness* and *interest in science*. Both males and females ranked *radio* as the most frequent source of scientific information. Within the female sub-sample this was followed by *free-to-air television* and then *newspapers*, while among the male sub-sample *newspapers* was ranked above *television*. Within the male response patterns, all online information sources attained the lowest frequency as sources of scientific information. While among females, social media was ranked slightly higher, just above *government announcements*, with the remaining three online channels of information still selected least frequently.

As per the expectation a greater proportion of urban respondents reported encountering science information more frequently across all 11 questionnaire items compared to rural respondents. Respondents within the urban sub-sample continued to display the overall national pattern of ranking science information sources, with *radio*, *newspapers* and *free-to-air television* being most frequently selected. Rural respondents similarly selected *radio* more often, followed by *free-to-air television* and then *newspapers*. The ranking of *online* media sources, despite response proportionality variations between the urban and rural sample, did not differ between the two geographic location sub-samples.

Respondents with higher educational attainment demonstrate a higher likelihood of accessing a greater number of science information sources. All educational attainment groups selected *radio*, *newspapers* and *free-to-air television* as the most frequent source of scientific information; however the relative ranking of these items did differ within groups. Respondents with pre-matric and completed matric education both selected *radio* as the most frequent source of science information. These selections were followed by *free-to-air television* and *newspapers* within the pre-matric group, while within the matric completed sub-sample, the order of these selections was reversed. Among the sub-sample with post-matric qualifications the selection order differed as *newspapers* was preferred over *radio* and followed by *free-to-air television.* Similarly, within this group the selection of *satellite pay television* and *social media* was higher than within all other groups, likely as a result of income differentials and associated costs of this technology. However, among all educational attainment groups, online media sources were least frequently selected as science information sources.

Within age classifications the response selection similarly reflected that of the overall national ranking order. These included *radio*, *newspapers* and *free-to-air television* as the most frequent selection options. All age classifications selected *radio* as the most frequent science information source, with *free-to-air television* following within those less than 20 years and those older than 60 years. Among respondents aged 20 to 59 years old *newspapers* was the next most frequent selection followed by *free-to-air television.* Respondents older than 60 years did demonstrate the lowest response proportions across all 11 items, particularly within the *online* media channels.

Chapter Ten

Descriptive Survey Results:

Science Engagement

"Scientists need to engage with society routinely, during periods of calm, not just during crises."

Dr Tolu Oni (2016)

Introduction

The development of a citizenry, appropriately skilled and aware of the enormous contribution science and technology makes to daily life and productivity remains essential to the continued development agenda. Toward enabling this, an understanding of the type and frequency of science engagement activities South Africans attend would be a *sine qua non*. However upon reviewing data availability it is strikingly apparent that there remains a dearth of domestic information in this respect. This chapter presents the findings from the science engagement assessment within the 2015 wave 2 of the Khayabus survey.

OVERALL NATIONAL RESULTS FOR SCIENCE ENGAGEMENT ACTIVITIES ITEMS[129]

Overall results within the science engagement question set are presented within the questionnaire categories and have undergone no recoding. Among the total sample, 4.0% of respondents selected the *don't know* response option and were therefore considered invalid. Results for the entire valid response (n = 3 345) is presented in chart 10.1.

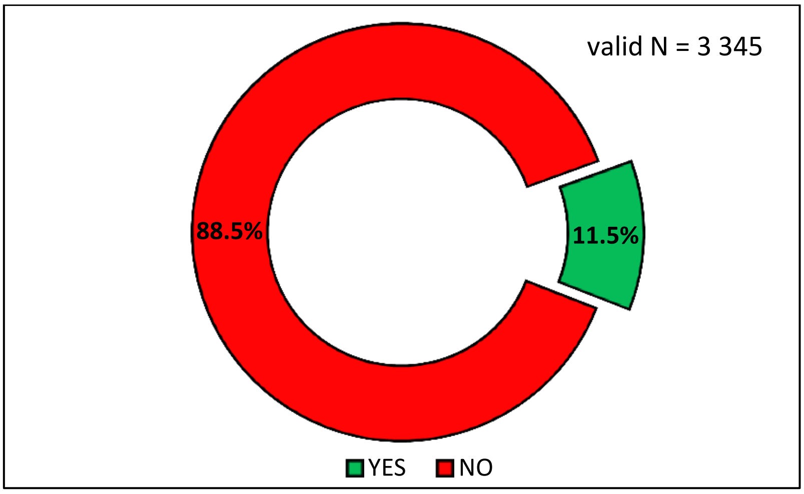


Chart 10.1: Overall result: South African science engagement activities assessment (Khayabus wave 2, 2015)

[129] The results of the reliability analyses are found in Appendices 2 to 7 (Page 410 - 442).

Across all 5 questionnaire items, it is apparent that the majority of South Africans have not recorded participation in any of the science engagement activities listed. While an average of 11.5% of the sample did report a visit to one of the science engagement locations, the majority (88.5%) reported that they had not attended one of the activities within the preceding 12 month period.

Within the valid sample (3 345), 950 unique respondents indicated that they had visited (at least) one of the five science engagement locations listed in the questionnaire. Among these 950 respondents, the majority indicated that they had attended a *public library* (34.5%); followed by a *zoo or aquarium* (22.8%) and any category of *museum* (18.3%). General public attendance at *science centres, technology exhibition*, *science café, festival or similar public events* was not expected to be very high as these do not inherently have a broad appeal beyond those with increased interest in scientific areas. Despite this, within the 950 respondents indicating a visit to any of the 5 science engagement activities listed, 12.5% had attended a *science centre* or *technology exhibition* while 11.9% indicated that attendance at a *science café, festival or similar public event* in the preceding 12 month period (see chart 5.132).

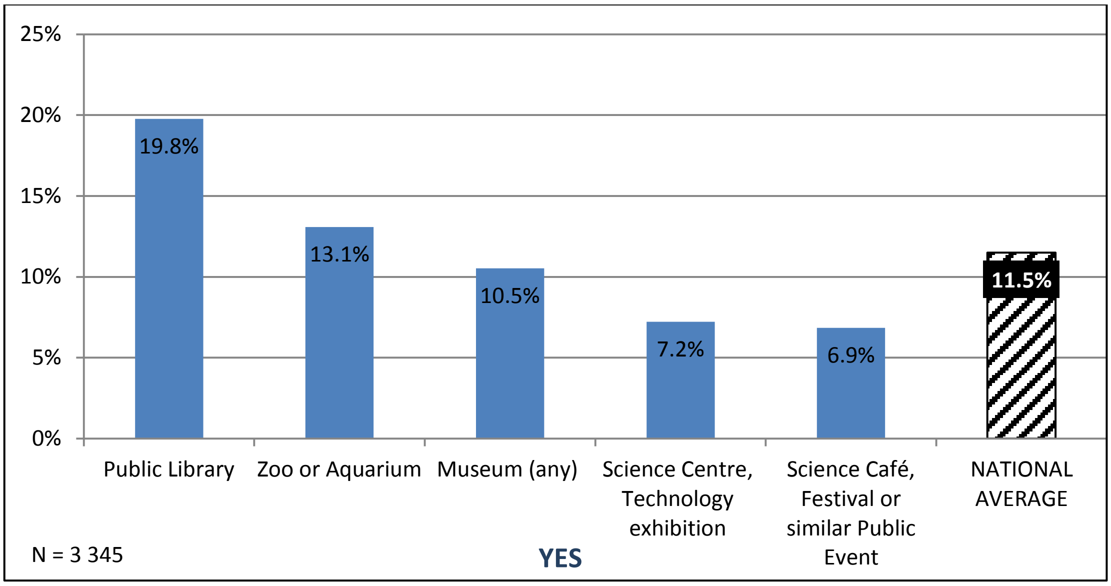


Chart 10.2: South African science engagement activities assessment: *YES* responses (% total valid)

Among the respondents that indicated attendance at one of the 5 activities listed, an assessment was done to ascertain how many of these respondents attended more than one type of science engagement activity[130]. The majority (48.2%) of respondents indicated that they had only visited one type of science engagement activity during the reference period. This proportion decreased by 50% for those visiting 2 and similarly again for those visiting 3 of the listed activities (see chart 10.3).

[130] To note this only represents the number of different types of science activities visited, and not the quantum of visits during the 12 month period.

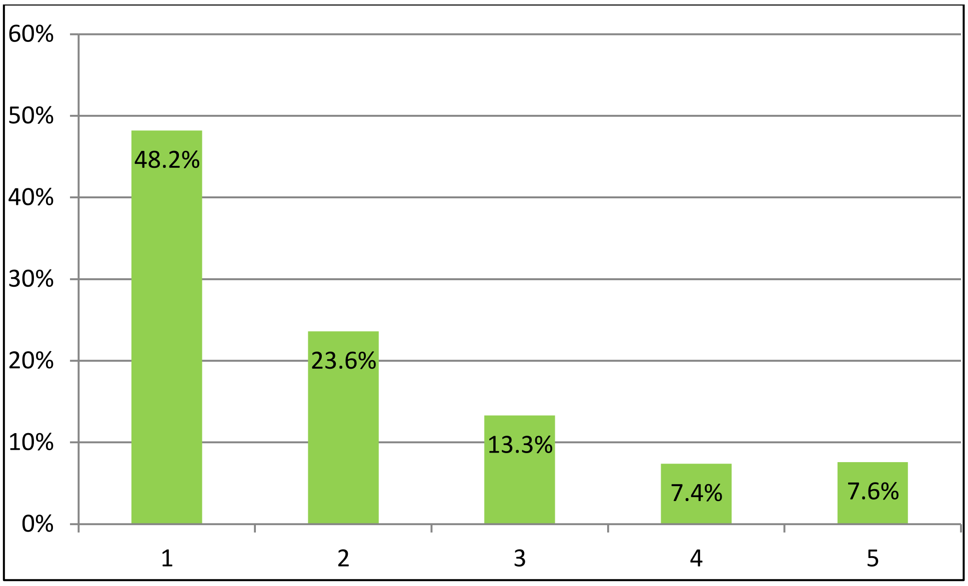


Chart 10.3: Science engagement activities: Number of activities attended

Very few respondents visited more than 3 science engagement activities, with only a very small proportion visiting 4 or 5 engagement locations.

Within the above overall results, it is clear that the majority of South Africans surveyed, did not attend any of the 5 science engagement activities listed. This is a particularly important finding within these results, as it is counter to the earlier presented evidence that a large share of South Africans report higher *interest* and *informedness* levels with regards to science.

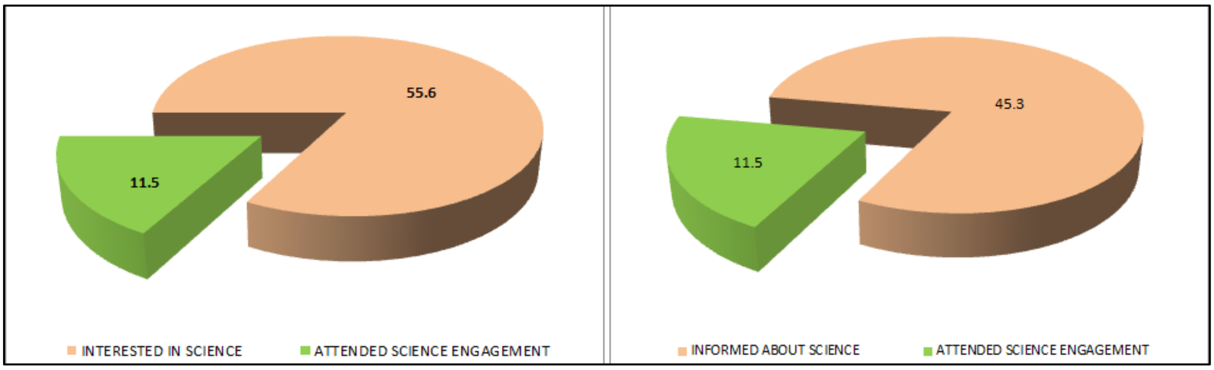


Chart 10.4: Science engagement result compared to Interest and Informedness in science data

Despite the fact that 55.6% of respondents reported an interest in science, and 45.3% reported a higher informedness across the 7 areas of science in the questionnaire, the vast majority of respondents (88.5%) do not attend engagement activities.

Result for the attendance at *science engagement activities* question will be further explored by the various demographic classifications within the next part of this chapter. The data will be presented within the following classifications: *race group; gender; geographic location; educational attainment* and *age*. Table 10.1 presents the average results across the 5 engagement items in the questionnaire and is further disaggregated by demographic classification groups.

	YES	NO	D/K	N
NATIONAL	**11.0%**	**84.9%**	**4.0%**	**3 486**
RACE	**N = 3 486**			
BLACK	9.6%	86.1%	4.4%	**2 523**
WHITE	21.0%	77.5%	1.5%	**408**
INDIAN / ASIAN	8.9%	88.4%	2.6%	**121**
COLOURED	10.7%	84.3%	5.0%	**434**
GENDER	**N = 3 486**			
FEMALE	10.7%	85.3%	4.0%	**1 747**
MALE	11.4%	84.5%	4.1%	**1 739**
GEOGRAPHIC LOCATION	**N = 3486**			
URBAN	13.6%	83.0%	3.4%	**2 297**
RURAL	6.1%	88.6%	5.3%	**1 189**
EDUCATION	**N = 3486**			
PRE-MATRIC	4.9%	90.1%	5.0%	**1 369**
MATRIC COMPLETED	12.6%	84.1%	3.3%	**1 578**
POST-MATRIC	22.0%	74.2%	3.8%	**539**
AGE	**N = 3 472**			
<20 YEARS	17.8%	79.2%	3.0%	**170**
20-29 YEARS	11.0%	84.4%	4.6%	**1 101**
30-39 YEARS	11.4%	85.2%	3.4%	**956**
40-49 YEARS	11.0%	85.1%	3.9%	**598**
50-59 YEARS	9.7%	86.3%	4.0%	**372**
60+ YEARS	7.2%	87.3%	5.5%	**275**

Table 10.1: Results of *Science engagement activities* by demographic classifications in Khayabus wave 2, 2015

Across the national sample of 3 486 respondents, race group classification was found to be significantly associated with attendance at science engagement activities (X^2=137.864, p < 0.001). White and coloured respondents demonstrated a greater attendance at science engagement activities compared to black and Indian / Asian respondents.

Within each of the 5 items, gender group classifications did not demonstrate a statistically significant association with reported respondent attendance at science engagement activities (X^2=17.521, p > 0.05). Male respondents did report a slightly higher proportional attendance at engagement activities, compared to females at the item level; this was not found to be significant.

Respondent location classification was found to be statistically associated with the responses to the science engagement activity items (rural / urban: X^2=91.949, p < 0.001; Province: X^2=219.723, p < 0.001). The provincial data indicates that the province with the highest proportion of individuals that attended science engagement activities was the Western Cape (41.6%). The Limpopo province attracted the lowest science engagement attendance scores (15.2%); however this may be related to the availability of these activities in that province. Location classification at the level of rural / urban demonstrated a similarly a significant variation in the results achieved within each of the location sub-samples (see table 10.1).

The level of respondent educational attainment demonstrated a significant association with reported attendance at science engagement activities (X^2=284.199, $p < 0.001$). A larger proportion of respondents with post-matric educational attainment attended science engagement activities within the preceding 12 month period, compared to those with a completed matric or pre-matric education.

Respondent age group classification was similarly found to display a statistically significant association with respondent reported attendance at science engagement activities (X^2=89.109, $p <$ 0.001). National average results indicate a decreasing attendance at science engagement activities with increased age. Respondents within the 60+ year's age group report the lowest attendance at science engagement activities.

These demographic variables will be explored in greater detail in terms of respondent response patterns within the next sections.

<u>EXPLORATORY ANALYSIS OF VARIABLES CORRELATING WITH SCIENCE ENGAGEMENT ACTIVITIES</u>

The variables included in the CHAID analysis for the science engagement question set included: *gender; race; household income; educational attainment; geographic location (rural-urban); employment* and *age.* The composite score across all engagement activities was used in the computation of the output from within this analysis. The output of the CHAID procedure was imported into Microsoft Excel and is presented graphically in Figure 10.1 below.

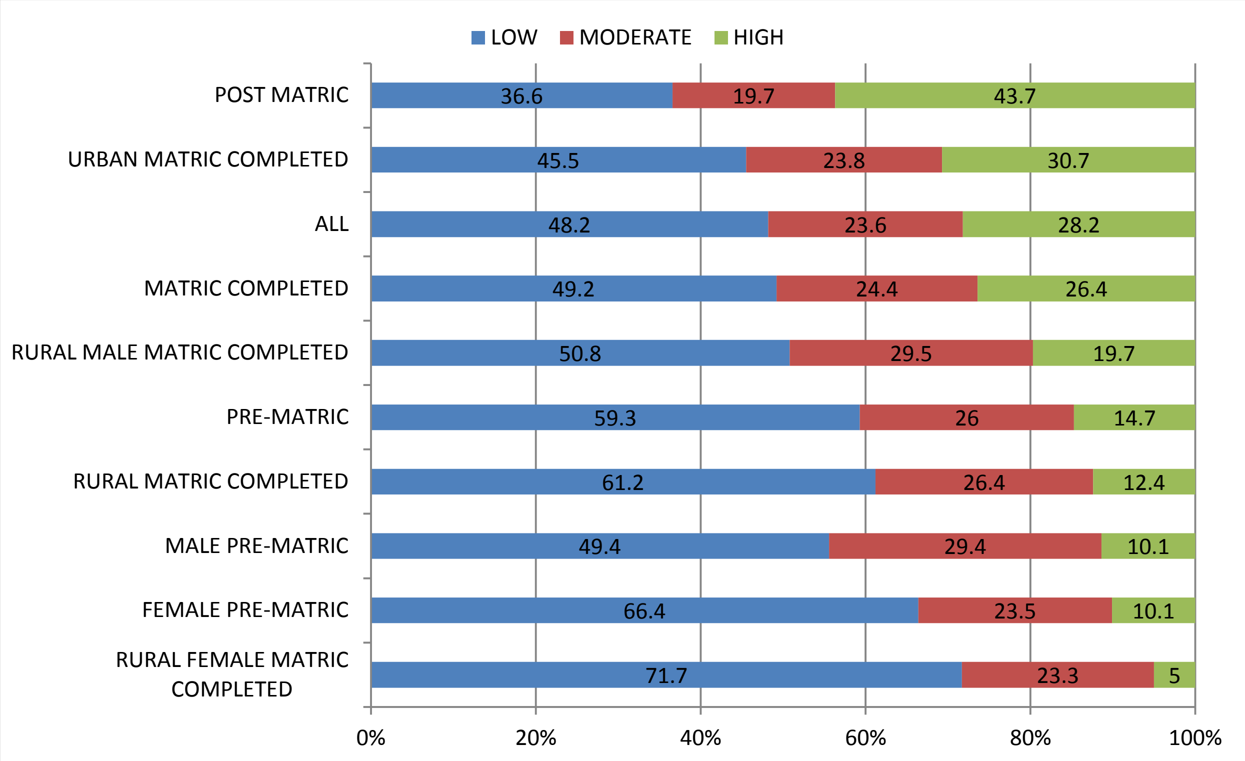


Figure 10.1: Output of CHAID analysis: Science Engagement activities

The results of the analysis reveal that among the seven variables considered, two are considered to be the best predictors of South African respondent attendance at science engagement activities. These variables include *educational attainment level* and *geographic location (rural-urban)*. Compared to the average across ALL respondents, individuals with a completed matric or higher educational level and reside in urban areas are 15.5% more likely to attend any of the five listed science engagement activities. At the other end, respondents not living within urban areas, and possessing lower educational attainment are less likely to attend science engagement activities.

These demographic variables will be explored in greater detail in terms of respondent response patterns within the next sub-sections. They will be further used, in conjunction with other conceptually and statistically significant variables within the multinomial logistic regression modelling, in a later chapter.

SCIENCE ENGAGEMENT ACTIVITIES BY GEOGRAPHIC LOCATION

Geographic location was shown to have a statistically significant influence on respondent science engagement activities (rural / urban: X^2=91.949, p < 0.001; Province: X^2=219.723, p < 0.001). Though these results will not be examined in great detail by provincial boundaries, table 10.1 lists the proportions of each provincial sample in terms of attendance at science engagement activities.

Western Cape	41.6%
Gauteng	33.1%
Mpumalanga	29.7%
Eastern Cape	23.3%
North West	21.0%
KwaZulu Natal	19.1%
Free State	16.8%
Northern Cape	15.3%
Limpopo	15.2%

Table 10.1: Provincial proportions of respondents attending science engagement activities

Within the provincial results, the Western Cape (41.6%) and Gauteng (33.1%) province reported the highest frequency of respondents attending science engagement activities within the reference period. This was followed by Mpumalanga (29.7%); the Eastern Cape (23.3%) and the North West (21.0%) province. All other provincial areas reported science engagement attendance less than 20%. This may in many ways be related to the availability of 4 of these activities within all the provincial areas.

Significantly lower proportions of rural (6.4%) respondents report attending science engagement activities, compared to respondents within the urban (14.1%) sub-sample. Rural respondents report an average attendance across the five science engagement activities just above half that of the national average (see chart 10.1).

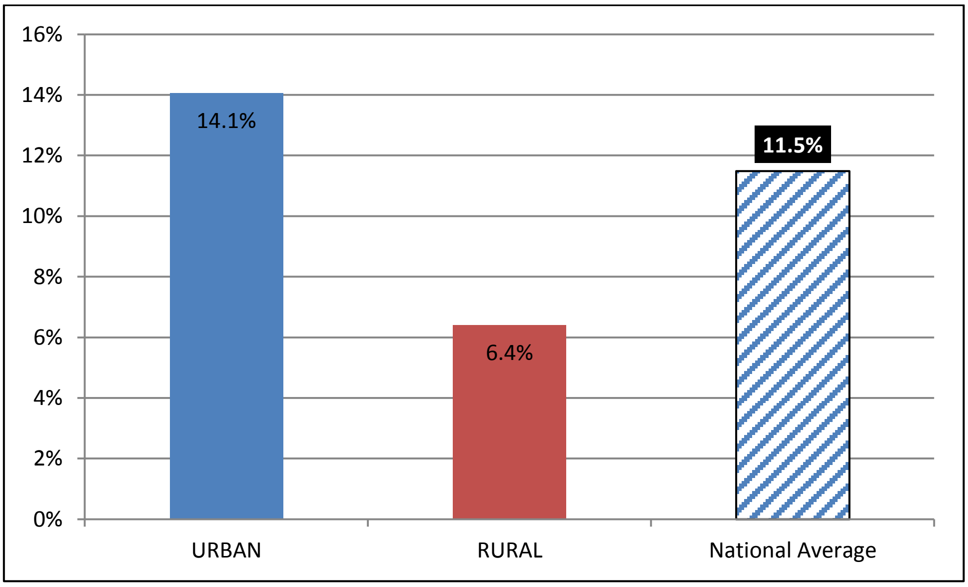


Chart 10.1: Average response by location group: *science engagement activities*

This variation in the reported proportions of rural and urban respondents attending these activities may be as a result of the previously discussed location and frequency of these activities outside of major metropolitan areas; however that cannot be shown within this data set.

The above is again demonstrated when looking at the number of science engagement activities attended within each of the rural and urban sub-samples (see chart 10.2). Across all items, urban respondents report increased attendance at science engagement activities, compared to rural respondents. While rural respondents do indicate higher attendance at between one and two science engagement activities, the proportions within this sub-sample are all below 1.5% for more than two science engagement activities.

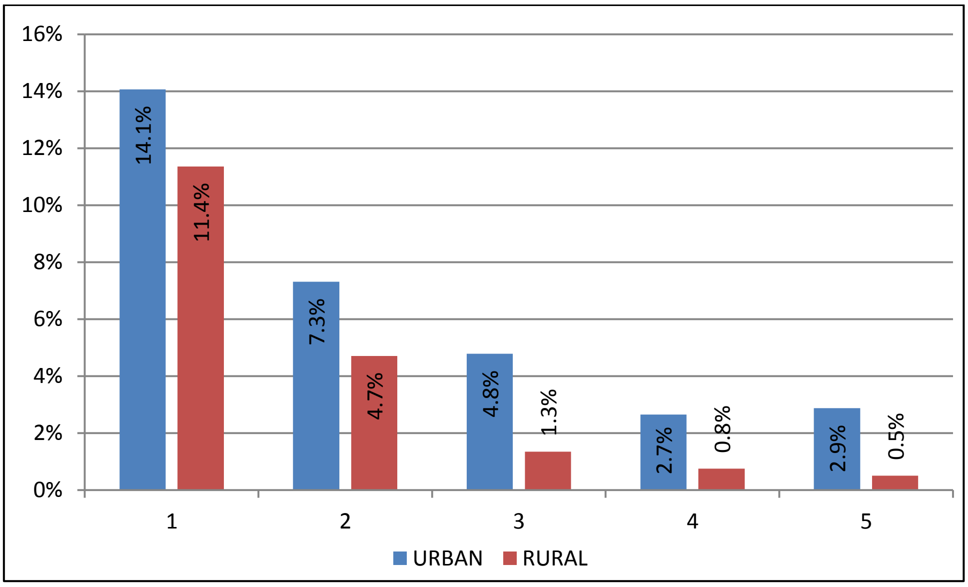


Chart 10.2: Science engagement activities: Number of activities attended

Urban respondents report the highest proportions for between one and three activities, however similarly low proportions are reported for four or more science engagement activities attended within the reference period.

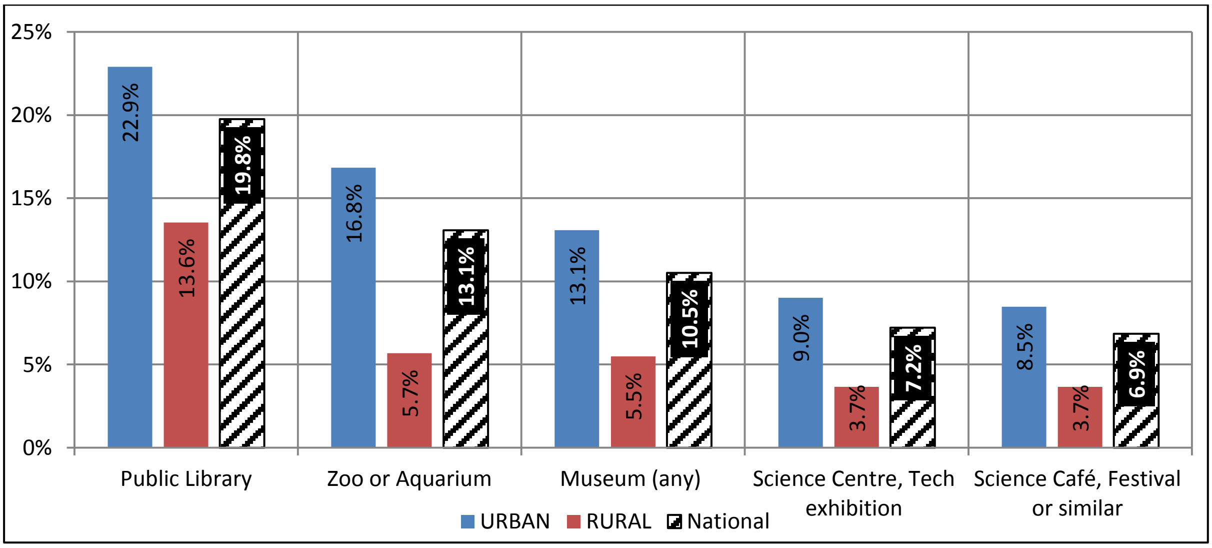


Chart 10.3: Science engagement activities attended by location group

The majority of respondents indicate attending a *public library*, *aquarium* or *museum*. Urban respondents report the highest proportions within each item. Within the rural sub-sample, the highest proportion was similarly reported within the item for *public library*, however responses in each of the four remaining categories was significantly lower for this sub-sample. Response for both sub-samples was lowest under *science centre, tech exhibition* and *science café*, *festival or similar event*.

Within the preceding sections of this chapter location group has been identified as demonstrating a significant association to response at the various survey items. Similarly within *interest*, *informedness* and *science engagement* this pattern continues and is presented within chart 10.4.

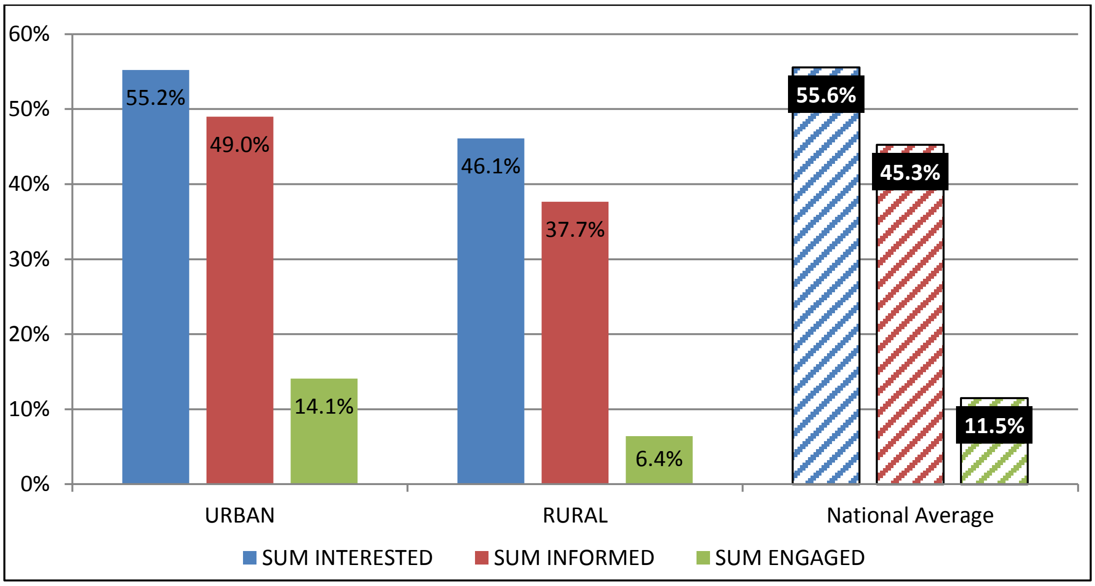


Chart 10.4: Science engagement result compared to *Interest* and *Informedness* in data by location group

Urban respondents generally achieved higher *interest* and *informedness* proportions compared to their rural counterparts. Similarly, urban respondents' attendance at science engagement activities, while significantly lower than the levels of *interest* and *informedness*, is proportionally higher than the level recorded within the rural sub-sample. Within each data element in chart 10.4, the rural response is below that of the national average.

SCIENCE ENGAGEMENT ACTIVITIES BY EDUCATIONAL ATTAINMENT

Educational attainment level was shown earlier to be significantly associated with attendance at science engagement activities (X^2=284.199, p < 0.001). Respondents with a post-matric education demonstrated a consistently higher outcome on the measures within this survey. Similarly within the science engagement questions, a significantly higher proportion of the *post-matric* (22.9%) participants reported attending any of the five science engagement activities, when compared to the *matric competed* (13.0%) and the *pre-matric* (5.1%) sub-samples (see chart 10.5).

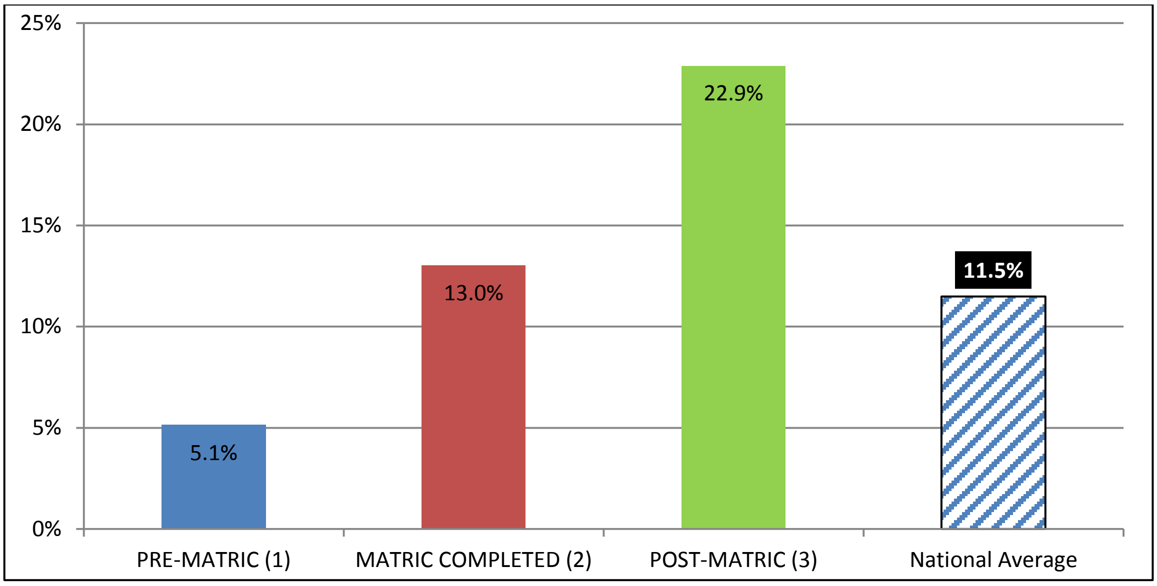


Chart 10.5: Average response by educational attainment group: *science engagement activities*

Respondents with post-matric education displayed significantly different science engagement attendance compared to respondents within the remaining educational attainment sub-samples. Respondents with pre-matric educational attainment present a higher proportion of attendance within one or two engagement activities; however do not demonstrate a similar pattern for more than three engagement activities. Within the categories for one and two activities attended, both matric completed and post-matric respondents demonstrate higher proportions of attendance, however this decreases for those with a completed matric, beyond three engagement activities.

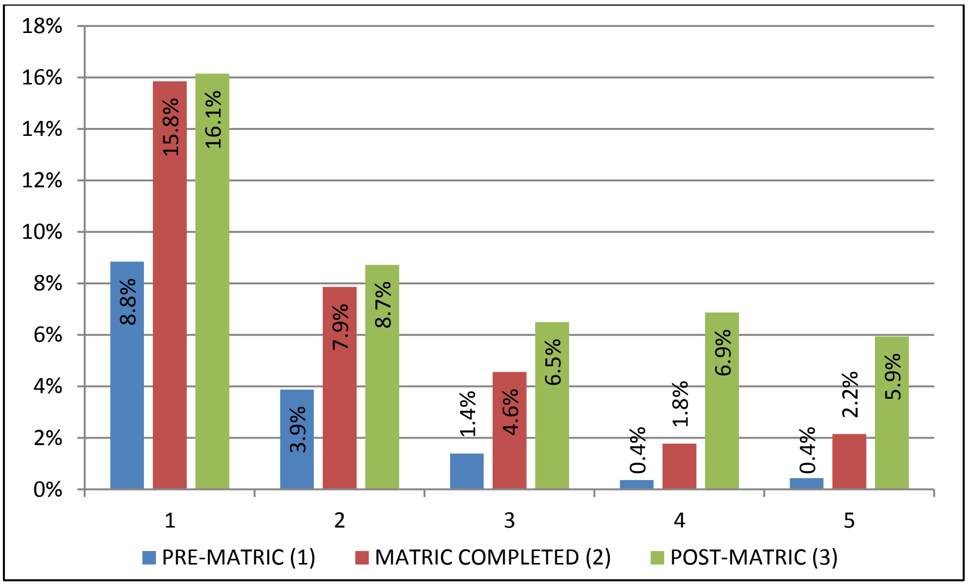


Chart 10.6: Science engagement activities: Number of activities attended

Those with post-matric educational attainment, report the highest attendance at science engagement activities across all educational attainment groupings. Across all items, respondents with post-matric education report the highest attendance frequency. However, this was highest for the *public library* and *zoo or aquarium* items (see chart 10.7).

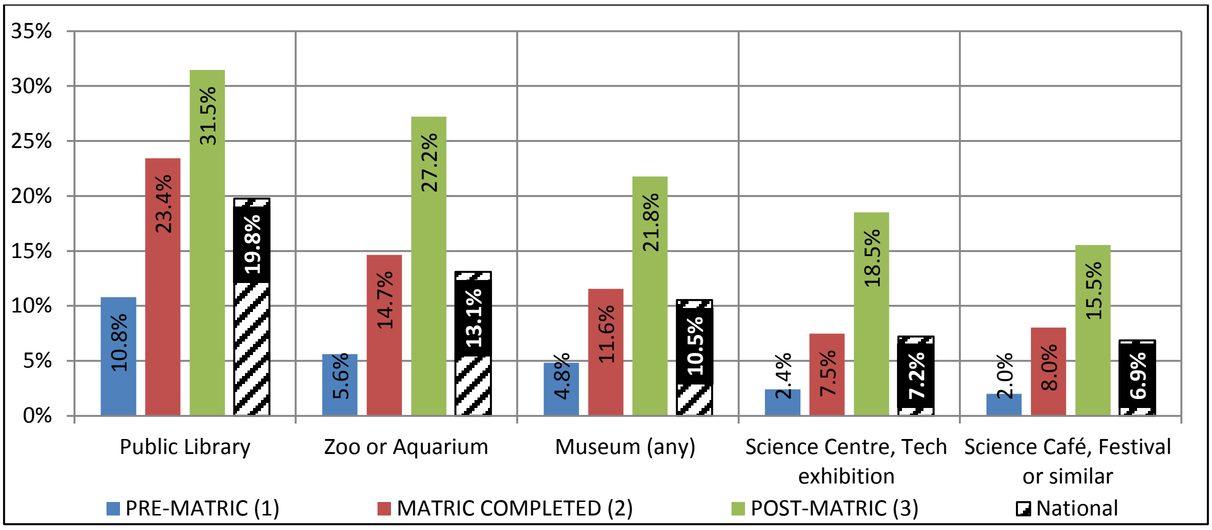


Chart 10.7: Science engagement activities attended by educational attainment group

The item for *museums* continued to attract a higher proportion of response compared to *science centre, tech exhibition and science café*, *festival or similar event*, wherein those with a pre-matric education have a particularly low proportional response. Across all three data items in chart 10.8, increases in educational attainment demonstrate similar increase in response on each data item.

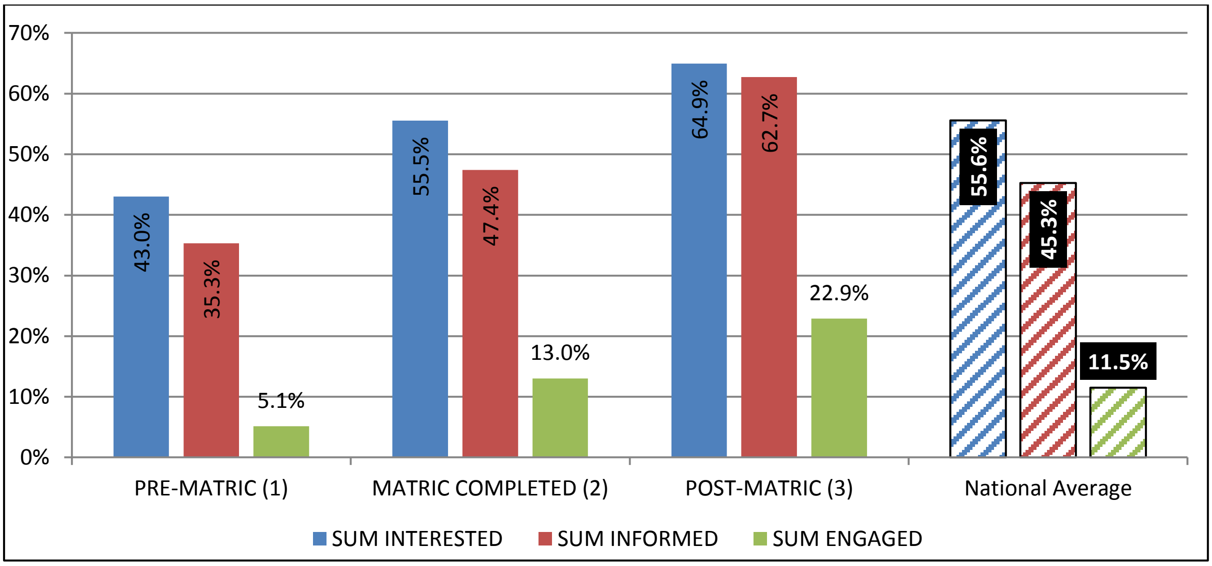


Chart 10.8: Science engagement result compared to *Interest* and *Informedness* data by educational grouping

Respondents with post-matric education demonstrate higher proportional *interest* and *informedness* outcomes. Similarly the variance between *interest* and *informedness* is lower for respondents within this higher educational attainment grouping, compared to those with matric completed of pre-matric education. Despite this, even those within the post-matric group still demonstrate a low engagement frequency, despite being significantly interested and informed than for respondents in lower educational attainment groups.

Conclusion

Among the most important findings within the results of this chapter is the level of science engagement activities attended by the general South African population. At the national level, only 11.5% of the survey sample (n = 3 486) report having visited any of the five science engagement locations listed in the questionnaire. The vast majority of respondents (88.5%) report not having attended a science engagement activity within the preceding 12 months. The most frequently visited science engagement activity within the total sample was *public libraries* followed by a *zoo or aquarium* and a *museum*. The selection options for *science centres, technology exhibitions* and *science café's; festivals or similar public event* received the lowest proportional response across all demographic classifications. The largest proportion of *yes* responders report having attended one type of engagement activity, with fewer respondents having visited two or three science engagement locations within the preceding 12 months.

Among race classifications, more white (21.3%) respondents report having visited a science engagement activity location within the preceding 12 months; followed by coloured (11.2%) and black (10.0%) respondents. Indian / Asian respondents report the lowest level of science engagement, with only 9.2% of respondents within this sub-sample indicating a *yes* response at any of the questionnaire items. Across all five engagement activity locations, white respondents report the highest proportions across all groups. However, compared to black and coloured respondents, Indian / Asian respondents reported a greater frequency of attendance at *science centres, technology exhibitions* and *science café's, festivals or similar public event*.

Male respondents report a higher proportion of attendance at science engagement activities, however this result was not found to be statistically significant. Both males and females report visiting a pu*blic library* followed by a *zoo or aquarium* and a *museum*; with response proportions being fairly equal between gender groups. More males report attendance at *science centres, technology exhibitions* and *science café's, festivals or similar public event* compared to females.

Within provincial boundaries, respondents within the Western Cape, Gauteng and Mpumalanga report the highest overall attendance at science engagement locations. The lowest proportion response was received within the Northern Cape and Limpopo provinces. Within rural / urban classifications, a greater proportion of urban respondents report attendance at science engagement locations compared to rural respondents. Attendance was more frequent at a pu*blic library* followed by a *zoo or aquarium* or a *museum* for both location sub-samples. Rural respondents however report significantly lower proportions within the four categories following pu*blic library*.

Validating the expectation, a higher proportion of respondents with increased educational attainment attended more science engagement activities within the reference period. Respondents with post-matric education were found to be 4.5 times as likely to visit one of the listed science engagement locations compared to those with pre-matric educational attainment. Individuals with pre-matric educational attainment report the highest proportional response within the questionnaire category for pu*blic library.* However, this decreases significantly in the remaining four science engagement response options. Respondents with a completed matric report higher proportions within pu*blic library* followed by visits to a *zoo / aquarium* or a *museum*. Within the post-matric educational attainment category, respondents report the largest proportional response across all five questionnaire categories.

Younger respondents attend a significantly higher number of science engagement activities, compared to older respondents. Respondents between the age of 20 and 49 years report a consistent level of attendance at any of the five engagement activities, however among those older than 50 years, reported attendance at these activities decreases. As within other demographic classifications attendance was highest at public libraries, followed by *zoo / aquarium* or a *museum*, with younger respondent's representing the majority of attendance selections. Reported attendance at *science centres, technology exhibitions* and *science café's, festivals or similar public* was generally low across the sample; however as with the highest educational groupings, younger respondents attended these events more frequently than their counterparts.

Chapter Eleven

Indicators & Predictors of the South African Public Understanding of Science

The critique of the public deficit model as a common sense prejudice among experts is valid, for certain, but its identification with the protocol of survey research is dysfunctional. Breaking this unfortunate mind frame of linking model and protocol will help to liberate and expand the research agenda.

Bauer, Allum and Miller (2007)

Introduction

Chapter Eleven continues as an extension to Chapter Ten, presenting the set of indicators produced within this research as well as the demographic predictors of outcomes within each indicator. The chapter presents these elements within two sections. The initial section describes the process of index construction, validation and reliability assessment; followed by the data outputs for each indicator. This is complimented by a section highlighting the statistical interactions between the six indicators. This sub-section concludes with a general public understanding of science audience segmentation, based on the outcomes of the survey findings.

The second section of this chapter is devoted to a discussion of the techniques and results from the analysis examining predictors of outcomes on each indicator to be presented. The significant predictors of outcomes are then presented within a predictive model for each indicator.

11.1 INDEX CONSTRUCTION and VALIDATION

An indicator is a composite measure that aggregates the response on multiple questionnaire items to provide summary information and rank-order on observations that represents the general dimension under investigation (Hawken and Munck, 2013). Within social research, and particularly quantitative studies, indicators are extensively used to arrive at more efficient data analysis and presentation methods. Composite data measures have three key advantages within research. Specific data of interest is often not accessible or too multifaceted to adequately understand within a single questionnaire item. This is particularly relevant for more complex research constructs such as *job satisfaction* or as is the case in the current research, *public understanding of science*. In these cases, it often requires data inputs from a number of questionnaire items to adequately address the research area of interest in a meaningful way. Secondly, indicators offer research the ability to score and rank-order data from multiple items into more distinct categories of response. Lastly, indicators enable data reduction of a variety of response variables into a smaller number of outputs (or a single output) in a manner that makes the result more accessible to a wider audience. The efficiency that this characteristic of indices introduces provides the researcher with the ability to relay the required level and detail of information, while ensuring the volume of data is minimised (Babbie, 2007). The power and precision that indicators offer research outputs is of particular importance within the field of *science communication* and the *public understanding of science* as it enables greater accessibility of data and information, requiring little background technical experience to interpret index outcomes.

This does however necessitate that indices are correctly constructed and validated prior to being implemented within research studies (Castro-Martínez et al, 2009). Babbie (2007) provides among the few comprehensive guides to effectively produce reliable indices. He notes the following four steps involved in index construction: *item selection; examination of empirical relationships, devising a scoring method* and *validation of the index.*

Item selection involves the inclusion of appropriate variables to measure the construct under consideration. This requires that all items carry a high degree of *face validity*, implying that all items should have a direct link to the subject area being measured. Within this step, the second requirement is that of *unidimensionality*. This implies that each item within the index should only measure a single dimension of the concept under investigation. Further to the unidimensionality aspect, the items selected should conform to a level of assessment that is predetermined. This relates to the *generality* or *specificity* of the items within the index and would ensure that the index remains focussed to the specific dimension of interest. The last consideration under this step requires that items offer a degree of *variance* within the data that allows for adequate discrimination of response across all the selected items.

The second step requires an *examination of empirical relationships* between the selected items in the index. Where items are found to be related to each other these items remain good candidates for inclusion in the index. The determination of empirical relationships often relies on the outputs of cross-tabulation procedures and an examination of *inter-item correlation matrices*. Everit (2002) and Field (2005) independently note that items with correlation values lower than 0.300 should be considered inappropriate for inclusion within an index. Many of these inter-item correlations and cross-tabulation results have been reported in chapters five through ten; however, selected empirical evidence of importance will be presented within the following sections.

The *scoring* of the items included allows for the composite measure to output a single variable that describes all of the items making up in index. Babbie (2007) notes the important consideration of the *range* of the index. This requires some trade-off between the *range of measurement* and the number of cases within each scoring point in the index. A maximum *range of measurement* would ensure that the extreme scores at both the *positive* and *negative* ends of the index are included; however, the distribution of response at either extreme may be insufficient for meaningful analysis. This was duly considered and applied within the development of the indicator set. An additional consideration within item scoring is the application of weighted or unweighted scores. It remains common practice to weight scores equally (or not weight) scores unless there remains conceptual or theoretical reasons to apply differential weighting to index scores.

The final step in index construction requires *validation of the index*. The initial process in index validation is *item analysis*. This provides an assessment of each items' independent contribution to the total index score. Two characteristics of item analysis are *item difficulty* and *item discrimination*. *Item difficulty* relates to the proportion of respondents who provided a correct response to the item. While *item discrimination* is a measure of response variation - on specific items - between known *high performers* and *low performers*. If *high performers* provided valid or correct responses more frequently than *low performers* then the item is considered to have an acceptable discriminatory property. The *item discrimination* index is presented as a ratio ranging between -1.0 and +1.0, where values above (or below) zero are preferable to a zero value[131]. Values above 0.20 are generally considered an acceptable discriminatory index ratio (Tredoux and Durrhiem, 2002). The next validation step involves *external validation* of the index. *External validation* requires that the entire index be tested for *validity* and *reliability*. Validity testing includes *content validity*, *criterion validity* and *construct validity*. *Content validity* refers to appropriateness and coverage of all aspects of the area of interest. C*riterion validity* is a measure of the predictive power of the measure compared to other measures presumed to be related. An example of this would be questions measuring the *importance of education*, which should be empirically predictive of response on questions relating to *educational achievement*. While *construct validity* refers to the degree to which the test measures what it is supposed to measure. Types of *construct validity* include *convergent* and *discriminant* validity. The final consideration under validation refers to the *reliability* of the items within the index. This is assessed using the split-half reliability assessment adopting the Cronbach's Alpha procedure.

11.2 INDICATORS of the SOUTH AFRICAN PUBLIC UNDERSTANDING of SCIENCE (SAPUS)

Many of the index construction criteria discussed above have already been presented within chapters five through ten (and the linked appendices) but will briefly be revisited. Requirements under *item selection* as well as an *examination of empirical relationships* have already been

[131] However positive values are usually more acceptable as negative values indicate that the item is questionable despite its negative discriminatory value.

discussed within this thesis and will be highlighted before addressing the process of *index scoring* and *index construction* in greater detail under each indicator.

Within item selection, Chapter Four presents the detailed procedures applied in adopting, adapting and selecting the final items to be included within each question set. Comprehensive literature reviews and comparisons of questionnaire items from a variety of empirical studies had been considered prior to making the final item selections for inclusion in the survey instrument. Within each index, all items carry a high degree of *face validity* within their respective question-set domains and have been included on this basis.

Unidimensionality implies that all items within a question set have a latent variable in common. Dimensionality of the items included was assessed adopting two approaches. The initial approach involved using factor analysis to ascertain the number of factor-components present within each question set. All questionnaire items within each question-set underwent factor analysis and the results are presented in table 11.1 below together with the reliability assessment output.

	Factor Analysis				Cronbach's Alpha
Question set	**KMO**	**Bartlett's Test of Sphericity**	**Eigenvalue**	**% of variance explained**	**Alpha**
Science knowledge	0.934	$p < 0.001$	5.271	53.486	0.911
Attitudes to Science	0.838	$p < 0.001$	3.114	71.214	0.939
Interest in Science	0.938	$p < 0.001$	5.080	68.118	0.936
Informedness in Science	0.940	$p < 0.001$	5.371	73.022	0.949
Science Information Sources	0.947	$p < 0.001$	7.156	69.398	0.946
Science Engagement	0.899	$p < 0.001$	4.080	77.047	0.943

Table 11.1: Result of factor analysis and reliability assessment

All questionnaire items, within their specific question set were found to contain a single factor-component with an e*igenvalue* greater than 1, as suggested by Slocum-Gori *et al* (2011). Each demonstrated a significant value for *KMO* and the *Bartlett's test of sphericity* (see table 11.1). These results point to the existence of a single latent variable within each question set. Further to the factor analysis, *reliability analysis* was performed adopting the Cronbach's Alpha (discussed in Chapter Five / Appendix 2). All items within each of the six question-sets achieved high *inter-item-correlation* values and similarly high values for *Alpha* (see table 11.1). With the large proportions of variance being explained within single factor-components as well as the high inter-item-correlation recorded within each question-set, it was concluded that each of the six indices are based on question-sets that reflect a single dimension of measurement. Therefore it remains reasonable to conclude that the measures adopted within this study demonstrate reasonable evidence of *unidimensionality* as a result of the factor analysis and reliability assessment outputs. However, research has indicated that no single method for demonstrating *unidimensionality* within a question-set is universally accepted (Hattie, 1985) and therefore this outcome remains an assumption within the present study.

Chapter Five (and Appendix 2) presented the questionnaire items and explores the relationships between variables across the data set. Numerous variables were found to be significantly associated within question sets and have further been found to be related across the questionnaire through the presented cross-tabulations. This chapter will not repeat what has been presented within the results of chapter five. However within the presentation of the indices (to follow) where appropriate significant empirical relationships within the data will be presented for each index and further describe evidence within this requirement of index construction.

The *index scoring* and construction procedures will be discussed for each indicator within the following sections of this chapter. All scores applied within each index were unweighted as no reasonable theoretical prescription could be found to deviate from this accepted practice. Greater detail of these procedures, per index, will be discussed within the appropriate sub-section.

Item difficulty and *item discrimination* assessments have previously been presented in Appendix 2[132], along with *reliability assessments* for each question set. Similarly, within Chapter Four and chapters five through ten, areas relating to *face, content and criterion validity* have previously been discussed and will not be repeated here. However, an assessment of *construct validity* was performed for each of the question sets to test both *convergent* and *discriminant validity*. In brief, convergent validity provides confirmation that measures theoretically related do in fact demonstrate such a relationship, while conversely, discriminant validity provides confirmation that measures that are not theoretically related do not show such a relationship (Campbell and Fiske, 1959). The method employed in assessing both convergent and discriminant validity was adopted from Henseler, *et al* (2015).

To test these sub-types of construct validity, the individual question sets as well as unrelated question sets were tested from within the survey data. As *attitudinal questions* share very little theoretical or empirical relatedness to the remaining question sets, these were used within the testing procedures to ensure that the various indices present an acceptable level of construct validity.

Within this procedure, each of the question sets was run within a SPSS factor analysis together with the attitudinal items. All required statistical test outputs were examined and found to be within the

[132] Where appropriate to the data, alternative reliability measures were presented elsewhere

acceptable range, and further analysis was completed[133]. Within the factor analysis each of the items within their respective question-sets loaded within its own component, further confirming the presence of two separate constructs for each question set. The *pattern matrix* output from the factor analysis was used to obtain the factor loadings for each of the items used to test validity. Within each question set, the average loading for each component was calculated and verified to be above 0.700. Each of the six question sets revealed an average factor loading across all constituent items within the question-set to be above the stated threshold value (0.700), suggesting a high degree of *convergent validity* across all question sets. Further to this, for each of the question-sets, the variance was extracted and an average variance across each comparison-pair[134] was calculated. The value of the *calculated average variance* was then compared to the *square of the correlation* value, for each question-set pair, and an assessment of *discriminant validity* was made. Where the value of the *calculated average variance* was greater than the *square of the correlation* value for each comparison pair, this would establish *discriminant validity* (Henseler, *et al*; 2015). Among all comparison-pairs each question set was found to demonstrate both *convergent* and *discriminant validity*, further adding to the overall *reliability* and *validity* measures of the indices to be presented.

The above sections have outlined the process of indicator development as well as the statistical quality assurance procedures required toward validating the production of new indicators. Similarly, the processes that have been completed within this research have been relayed within section 11.2, setting the foundations for the presentation of the final indicator series. Within the next sub-section, details relating to the development, construction and scoring of the six indices produced within this research will be presented. This will be followed by the presentation of the overall national result for each indicator as well as specific comparisons of results within selected demographic sub-samples.

11.2.1 *Science Knowledge Index*

The *Science Knowledge Index* was developed from the 9-item science knowledge assessment questions. These questions (described in chapters four and five) covered 7 scientific disciplines and were designed to cover general aspects of scientific information. Furthermore all nine items within the question set were developed with a social application context as the foundation that minimised the requirement of higher technical knowledge proficiency within any of the disciplines included. As a result all questions should be answerable by respondents with a minimum of grade 11[135]

[133] Specifically KMO and Bartlett's Test of Sphericity were examined as well as observing the correlation values.
[134] *Knowledge-Attitude*; *Attitude-Interest*; *Informedness–Attitude* etc.
[135] In South Africa, this is a senior high school level, though not the high school exit year (grade 12)

educational attainment – which includes approximately 60% of the total sample[136]. The items making up the science knowledge question set are again presented in table 11.2 below.

Knowledge Area	TRUE	FALSE	D/K
In the majority of cases, HIV causes AIDS in humans	1	2	8
Lightning never strikes the same place twice	1	2	8
South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	1	2	8
The continents which we live on are continually moving due to forces deep within the Earth	1	2	8
The price of petrol in South Africa is NOT influenced by the price of crude oil	1	2	8
Schizophrenia is the same as Multiple Personality disorder	1	2	8
The father carries the genetic material that will determine if a baby is a boy or a girl	1	2	8
The earth's climate has NOT changed over millions of years	1	2	8
The main purpose of the Square Kilometre Array (SKA) radio telescope is to search for extra-terrestrial life	1	2	8

Table 11.2: Science knowledge assessment question set

The results for the science knowledge question-set were recoded for the development of the *Science Knowledge Index* to best facilitate the most appropriate scoring option. A correct response was coded as 1, while an incorrect (including *don't know*) response was coded as 0 (zero). This enabled a *SUM knowledge score* to be developed for each respondent within the sample. The *SUM knowledge score* variable was computed within SPSS and ranged from 0 to 9, representing the count of correct responses for each respondent. Within the total response, 298 respondents did not provide a single correct response and these were considered *invalid* within the index construction. The remaining 3 188 (91.5%) responses constituted the *valid* response and table 11.3 presents the response frequency as well as the sample proportion within each scoring category.

	SUM Knowledge Score (across 9 items)	Frequency	Percent	Valid Percent
Invalid	0	298	8.5	
Valid	**1**	228	6.5	7.2%
	2	383	11.0	12.0%
	3	568	16.3	17.8%
	4	870	25.0	27.3%
	5	599	17.2	18.8%
	6	355	10.2	11.1%
	7	149	4.3	4.7%
	8	35	1.0	1.1%
	9	1	0.0	0.0%
	Total	3486	100.0	100.0

Table 11.3: Science knowledge assessment SUM knowledge score distribution

As there is a pronounced gap within the literature providing grounding for the creation of knowledge response categories to facilitate scoring of response, two options were considered toward converting the *SUM knowledge score* into an index classification system. The initial scoring option considered three equal divisions, as a *theoretically driven* solution within the possible maximum score of 9. This resulted in the creation of 3 response levels, within the *SUM knowledge score*

[136] Educational attainment categories do not reflect individual grade but only categories for *some high school* and *matric completed*

distribution. Those scoring between 1 and 3 were considered to be a *low* knowledge group; those scoring between 4 and 6 were considered to be a *moderate* knowledge group while those scoring between 7 and 9 were considered to be a *high* knowledge group. Upon review[137] this resulted in an unsustainable distribution within the index, as the high end of the index contained too small a proportion of response (5.3%) compared to the low scoring group (33.6%). Following this initial review, an *empirically driven* scoring option was considered, wherein the distribution of scores was firstly considered and then classification cut-off points were computed within SPSS. The computed response percentile groupings were similarly developed at 33% response intervals. This led to a final *Science Knowledge Index* scoring template, based on the *SUM knowledge score* wherein respondents attaining a score of between 1 and 3 remained within the *low* knowledge group; those scoring 4 were considered in a *moderate* knowledge group while those scoring between 5 and 9 were considered in a *high* knowledge group.

	SUM Knowledge Score (across 9 items)	**Frequency**	**Classification Group**	**% Per Group**	**Count Per Group**
Invalid	0	298	**Invalid**	**8.5**	**298**
Valid	**1**	228	**LOW**	**33.8**	**1179**
	2	383			
	3	568			
	4	870	**MODERATE**	**25.0**	**870**
	5	599	**HIGH**	**32.7**	**1139**
	6	355			
	7	149			
	8	35			
	9	1			

Table 11.4: *Science Knowledge Index* scoring template: SUM knowledge score distribution

A new variable was created in SPSS called *Knowledge Index* that recoded response based on the *empirically driven* scoring solution and the results based on this are presented in the next section

[137] With the research supervisor

Index Data Output and Analysis

The overall national result for the *Science Knowledge Index* is presented in chart 11.1 below. Results within the Science Knowledge Index indicate that 37.0% of the sample was classified as being within the low scientific knowledge category; 27.3% were classified as having moderate scientific knowledge; while 35.7% were classified within the high scientific knowledge classification.

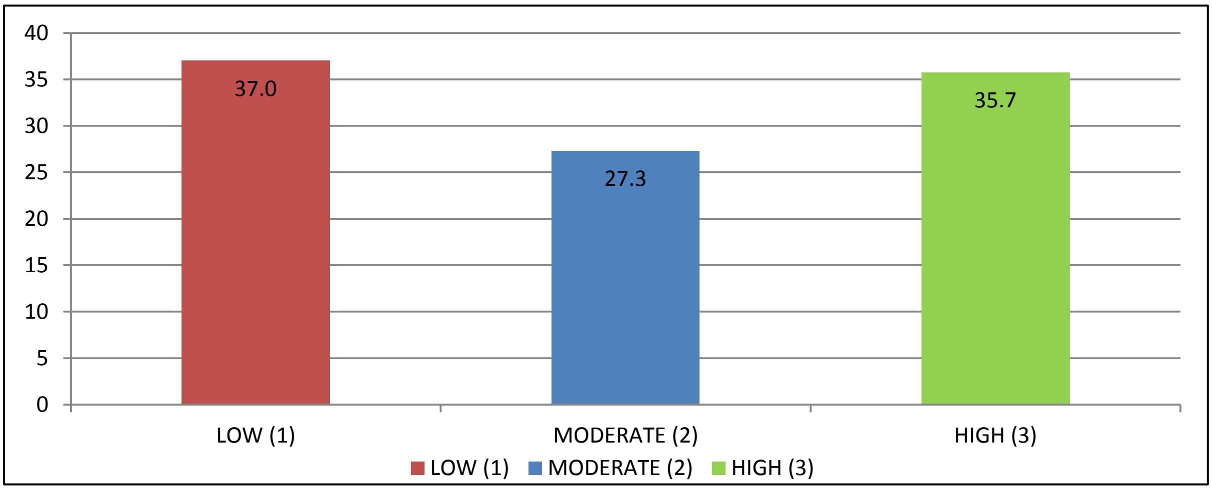


Chart 11.1: *Science Knowledge Index* overall national result (2015)

These results indicate that the marginally larger proportion of the total sample was found to have a low level of scientific knowledge, compared to those classified within the high knowledge category. While this was not entirely unexpected as a result of the level of inequality still within the many facets of contemporary South Africa, the result is none-the-less positive. A combined 63.0% of respondents were either classified as possessing a *moderate* to *high* level of scientific knowledge, based on results of the 9-item knowledge assessment question, which remains an encouraging indicator of the South African public understanding of science.

11.2.2 *Index of Attitudes to Science*

The *index of attitudes to science* was developed based on the response to the 4 attitudinal items within the questionnaire (see Chapter Four). These items were developed or adopted from various sources and were deliberately included based on either their *supportive* or *critical* position with regards to science. Items 1 and 3 adopt a greater *supportive* or *promise* position regarding science, while items 2 and 4 demonstrate a greater *critical* or *reservation* position. The attitudinal question set items are reproduced below in table 11.5.

	#	Attitudinal Statement	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	D/K
P	1	Science and technology are making our lives healthier, easier and more comfortable	1	2	3	4	5	8
R	2	It is not important for me to know about science in my daily life	1	2	3	4	5	8
P	3	Thanks to science and technology, there will be more opportunities for the future generation	1	2	3	4	5	8
R	4	The application of science and new technology makes our way of life change too fast	1	2	3	4	5	8

Table 11.5: Attitudes to science assessment question set

The data output for the attitude to science assessment underwent a number of recoding procedures for use in different applications (see Chapter Four and Six). Across all recoding, scientific reservation items (item 2 and 4) were reverse coded to ensure that the items remained within the same scale with regard to direction. The coding structure is discussed in Chapter Four and Chapter Six however is reproduced below (table 11.6).

PROMISE ITEMS (ITEMS 1 AND 3)

POSITIVE ITEMS (1 & 3)					
STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE	DK
1	0.5	0	-0.5	-1	8

RESERVATION ITEMS (REVERSE CODED – ITEMS 2 AND 4)

CRITICAL ITEMS (2 & 4)					
STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE	DK
-1	-0.5	0	0.5	1	8

Table 11.6: Attitudinal items recoding structure

Within the promise items, all *agree* responses were coded with a positive scoring point while all *disagree* responses were coded with a negative score. Within the reservation items, this scoring system was *reversed*, where *agree* responses were coded with a positive scoring point, and *visa* *versa* for the *disagree* items. This scoring system allowed for the development of a *SUM attitude score* variable within the data set that produced a net-sum total for each respondent across the 4 attitudinal items in the questionnaire. The *SUM attitude score* was within a range from -4.0 to +4.0, with negative scores reflecting a greater negative attitude to science, while positive scores demonstrated a greater positive attitude. Respondents realising a net-sum score equal to zero (0) were considered to possess *a degree of attitudinal ambivalence*, as their response to scientific promise and reservation attitudinal statements did not produce a sufficient level of distinction in their respective scores. Across the total sample (n = 3 486), 175 respondents selected the *don't know* option and were considered *invalid* response. This yielded a total number of valid responses of 3 311 respondents (95.0%) obtaining a valid score to be considered within the *attitudes to science* index construction.

Total Attitudinal score (across 4 items)	**Frequency**	**%**	**Valid %**
-4.0	0	0.0%	0.0%
-3.5	0	0.0%	0.0%
-3.0	2	0.1%	0.1%
-2.5	9	0.3%	0.3%
-2.0	19	0.5%	0.6%
-1.5	48	1.4%	1.4%
-1.0	177	5.1%	5.3%
-.50	386	11.1%	11.7%
.00	1 209	34.7%	36.5%
.50	548	15.7%	16.6%
1.0	420	12.0%	12.7%
1.5	232	6.7%	7.0%
2.0	204	5.9%	6.2%
2.5	39	1.1%	1.2%
3.0	12	0.3%	0.4%
3.5	2	0.1%	0.1%
4.0	4	0.1%	0.1%
VALID	**3 311**	95.0%	100.0%
MISSING	175		
	3 486		

Table 11.7: *SUM attitude* score distribution

Across the 4 items, each respondent's *SUM attitude* score produced a single output that continued to demonstrate the strength and direction of the attitudinal position. Scores ranging between -4.0 and -2.0 were indicative of stronger negative attitudes, while scores between -1.5 and 0.5 represented weaker negative attitudes. A similar scoring structure exists on the positive side of the *SUM attitude* score distribution (table 11.7). Scores equal to 0 (zero) were indicative of the presence of an ambivalent attitude. As a result of the low frequencies within the extreme ends of the *SUM* *attitude* score distribution, the decision was taken[138] to collapse the two positive and two negative attitude categories into single positive and negative attitudinal categories. This yielded a final scoring solution that produced three attitudinal classifications within the *index of attitudes to science*.

Total Attitudinal score (across 4 items)	Frequency	CLASSIFICATION GROUP	% PER GROUP	COUNT PER GROUP
-4.0	0	NEGATIVE	19.4%	641
-3.5	0			
-3.0	2			
-2.5	9			
-2.0	19			
-1.5	48			
-1.0	177			
-0.5	386			
.00	**1 209**	**AMBIVALENT**	**36.5%**	**1 209**
0.5	548	POSITIVE	44.1%	1 461
1.0	420			
1.5	232			
2.0	204			
2.5	39			
3.0	12			
3.5	2			
4.0	4			
VALID	**3 311**	**INVALID**	**5.0%**	**175**
INVALID	175			
	3 486			

Table 11.8: *Index of Attitudes to Science:* SUM attitude score distribution

Respondents scoring below zero (0) were classified within the *negative attitude to science* classification; those scoring zero (0) were classified as being *attitudinally ambivalent*, while those scoring above zero were classified within the *positive attitude to science* level of the index.

Index Data Output and Analysis

National results within the *Index of Attitudes to Science* reveal a South African population generally displaying more positive attitudes to science. Chart 11.2 indicates that 44.1% of South Africans survey presented a generally more positive attitude to science across the 4 attitudinal statements, while 19.4% presented a generally more negative attitudinal position. Despite this overall positive result, at a national level, 36.5% of respondents presented a degree of attitudinal ambivalence, where their specific attitudes were simultaneously positive and negative toward the questionnaire items, thereby producing no clear attitudinal direction within their response. As noted in *Chapter*

[138] After consultation with the research supervisor

Five, ambivalent attitudes are less desirable than either positive or negative positions as they are inherently more flexible toward change, in the face of additional informational inputs.

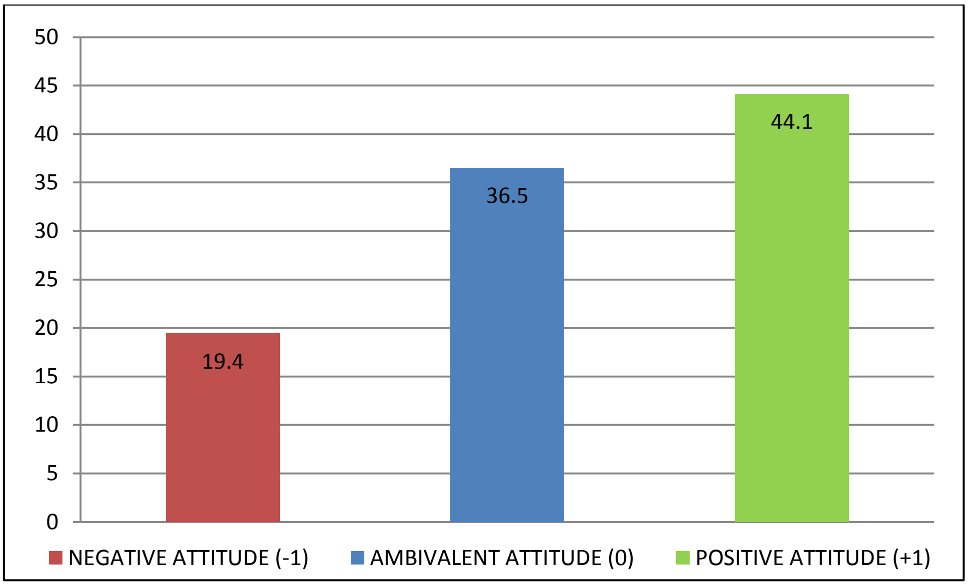


Chart 11.2: *Index of Attitudes to Science* overall national result (2015)

While the recorded proportion of South Africans presenting attitudinally ambivalent positions remains a concern as an outcome of this research, overwhelmingly South Africans present positive attitudes toward science which is a significant finding with regards to the overall South African public understanding of science.

11.2.3 *Index of Interest in Science*

Response to seven questionnaire items was employed in the development of the *Index of Interest in Science*. The seven items included in the *interest in science* assessment have been discussed in Chapter Six and are directly related to the *science knowledge* and the *informedness in science* questionnaire items. The questionnaire structure is again presented in table 11.9 below.

INTEREST AREA	VERY interested	MODERATELY interested	NO interest	D/K
Medical Science	1	2	3	8
Climate Change	1	2	3	8
Technology and the Internet	1	2	3	8
Politics	1	2	3	8
Economics	1	2	3	8
Astronomy	1	2	3	8
Energy	1	2	3	8

Table 11.9: Interest in science assessment question set

The response options were coded within SPSS toward the development of a total *SUM interest* score for each respondent. An initial scoring option revised and reversed the questionnaire coding, such that a *higher* coding value would relate to an increase in reported *interest* in science. As such all *don't know* response was coded as 0 (zero); *no interest* was coded as 1; *moderately interested* as 2 and *very interested* was coded as 3. Following input from the research supervisor, it was decided to revise this coding structure to achieve two corrective steps. The inclusion of *don't know* selections within the *SUM interest* score would introduce a confounding effect and this was to be excluded as invalid response. The second corrective measure was to revise the coding of the items, such that the response option for *no interest* reflected the lowest possible score equal to zero (0); *moderately interested* as 1 and *very interested* was coded as 2. Within the scoring of the *SUM interest* for each respondent, a process was followed to remove all invalid response. Within this process, all *don't know* selections as well as response within the *no interest* option (coded as zero) were considered invalid response. Together, these two categories of invalid response accounted for 846 respondents, whom were excluded from the input data leading toward the index development. This revised coding structure enabled scoring of the interest in science questionnaire items toward a final *SUM interest* score. The *SUM interest* score was calculated as a minimum of 1 and a maximum of 14 for each respondent, based on the valid response coding of *moderately interested* as 1 and *very interested* coded as 2, across 7 questionnaire items. The total valid response was 2 640 respondents (75.7%), that went on toward the development of the *Index of Interest in Science*.

	SUM Interest score (across 7 items)	Frequency	%	Valid %
Invalid	0	737	24.3	
Valid	**1**	206	5.9	7.8%
	2	222	6.4	8.4%
	3	212	6.1	8.0%
	4	223	6.4	8.4%
	5	180	5.2	6.8%
	6	236	6.8	8.9%
	7	343	9.8	13.0%
	8	162	4.6	6.1%
	9	159	4.6	6.0%
	10	185	5.3	7.0%
	11	147	4.2	5.6%
	12	131	3.8	5.0%
	13	60	1.7	2.3%
	14	174	5.0	6.6%
	VALID	**2640**	**75.7%**	**100.0**
	NO INTEREST	**737**	21.1%	
	MISSING (D/K)	109	3.1%	
	TOTAL	**3486**	100.0%	

Table 11.10: *SUM interest* score distribution

Within this distribution, respondents obtaining a SUM interest score between 1 and 4 were classified as the *low interest* group; those attaining a score of between 5 and 8 as the *moderate interest* group and respondents scoring between 9 and 14 as the *high interest* group.

SUM Interest score (across 7 items)	Frequency	CLASSIFICATION GROUP	COUNT PER GROUP	valid % PER GROUP
1	206	**LOW**	**863**	**32.7%**
2	222			
3	212			
4	223			
5	180	**MODERATE**	**921**	**34.9%**
6	236			
7	343			
8	162			
9	159	**HIGH**	**856**	**32.4%**
10	185			
11	147			
12	131			
13	60			
14	174			
VALID	**2640**	75.7%		
TOTAL	**3486**			

Table 11.11: *Index of Interest in Science - SUM interest* score distribution

The classifications were adopted within the final scoring solution and development of the *index of interest in science* (see table 11.11).

Index Data Output and Analysis

The national output from within the *index of interest in science* reveals an overall even distribution across the three *interest in science* outcome categories. Responses within the *moderate* category were slightly higher than for the high and low interest levels among the sample of South Africans older than 18 years old.

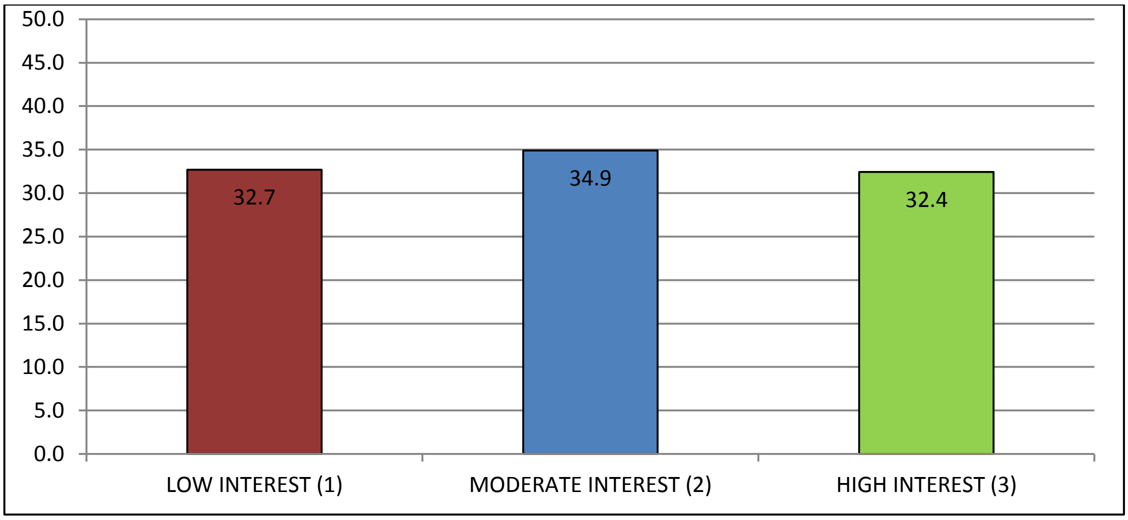


Chart 11.3: *Index of Interest in Science* overall national result (2015)

The result presented in chart 11.3 remains a positive outcome as it denotes the importance of a spread of *interest levels* within the population. Not all members of society will intrinsically exhibit a high level of interest in science, and this should not be an expectation on all citizens. It remains important to note that while interest may demonstrate some variation over time, the categories within the *index of interest in science* represent all respondents indicating *some level of interest*, which across the entire sample was 75.7%. This remains a meaningful proportion of the sample declaring a *level of interest in science*, as opposed to those indicating *no interest*. Falk, *et al* (2007) demonstrated the importance of lifelong learning and the central influence interest and curiosity exerts over information acquisition and understanding of science. Thus, within a practical and policy context, *interest* in science remains an important factor in motivating knowledge seeking behaviour and ultimately may provide an overall contribution to an enhanced national public understanding of science.

11.2.4 *Index of Informedness about Science*

Analogous to the construction of the *interest* index, the 7-item informedness in science questionnaire item was used in the construction of the *Index of Informedness about Science*. The question structure is presented in 11.12 below.

INFORMEDNESS AREA	VERY well informed	MODERATELY well informed	NOT well informed	D/K
Medical Science	1	2	3	8
Climate Change	1	2	3	8
Technology and the Internet	1	2	3	8
Politics	1	2	3	8
Economics	1	2	3	8
Astronomy	1	2	3	8
Energy	1	2	3	8

Table 11.13: Informedness in science assessment question set

As within the previous indices, response to the 7-item question set were recoded toward the development of a *SUM Informedness* score for each respondent. Responses were coded to reflect increasing levels of informedness within increases in score value. Accordingly, response under *not well informed* was coded 1; *moderately well informed* was coded as 2 while *very well informed* was coded as 3 within an initial coding and scoring procedure.

	SCORE ACROSS 7 ITEMS	Frequency Count	Frequency %	Valid %
Invalid	0	140	4.0%	
Valid	**1**	**26**	0.7%	0.8%
	2	**35**	1.0%	1.0%
	3	**16**	0.5%	0.5%
	4	**23**	0.7%	0.7%
	5	**21**	0.6%	0.6%
	6	**31**	0.9%	0.9%
	7	**946**	27.1%	28.3%
	8	**277**	7.9%	8.3%
	9	**252**	7.2%	7.5%
	10	**232**	6.7%	6.9%
	11	**193**	5.5%	5.8%
	12	**165**	4.7%	4.9%
	13	**177**	5.1%	5.3%
	14	**272**	7.8%	8.1%
	15	**127**	3.6%	3.8%
	16	**117**	3.4%	3.5%
	17	**124**	3.6%	3.7%
	18	**92**	2.6%	2.7%
	19	**76**	2.2%	2.3%
	20	**49**	1.4%	1.5%
	21	**95**	2.7%	2.8%
	Total	3486	100.0%	96.0%

Table 11.13: *SUM informed* score distribution

All response within the *don't know* option was considered invalid and was not included within the *SUM Informedness score* generation. Within the sample, 140 respondents selected the *don't know* option and the total valid response within this index development process was 3 346 (96.0%). The *SUM Informedness score* was calculated by adding the sum of individual respondent selections, based on the above discussed scoring method and obtaining a value ranging between 1 and 21[139]. Within the initial scoring option, response frequencies were divided equally based on the *SUM Informedness score* frequencies of respondents. This yielded three equal groups within the data. On the advice of the research supervisor, the group structure was amended, as a result of a review of the empirical distributions within each response category. The final structure of the index scoring and grouping was thus attained and is presented in table 11.14.

SUM Informedness score (across 7 items)	FREQUENCY	CLASSIFICATION GROUP	COUNT PER GROUP	valid % PER GROUP
1	26	LOW	1098	32.8%
2	35			
3	16			
4	23			
5	21			
6	31			
7	946			
8	277	MODERATE	1119	33.4%
9	252			
10	232			
11	193			
12	165			
13	177	HIGH	1129	33.7%
14	272			
15	127			
16	117			
17	124			
18	92			
19	76			
20	49			
21	95			
VALID	**3346**			
Total	3486			

Table 11.14: *Index of Informedness about Science: SUM informed* score distribution

Respondents obtaining a *SUM Informedness* score of between 1 and 7 were classified as the *low Informedness* group; those scoring between 8 and 12 were classified as the *moderate Informedness* group while respondents scoring between 13 and 21 were classified as the *high Informedness* classification.

[139] Maximum score per each of the 7 questionnaire items = 3, across 7 items the maximum score = 21

Index Data Output and Analysis

The national result for *Index of Informedness about Science* reveals a similar trend to that of the interest in science index. Response within the *high* informedness category was marginally higher, however, overall there is an even spread in response within each outcome of the *Index of Informedness about Science* (see chart 11.14).

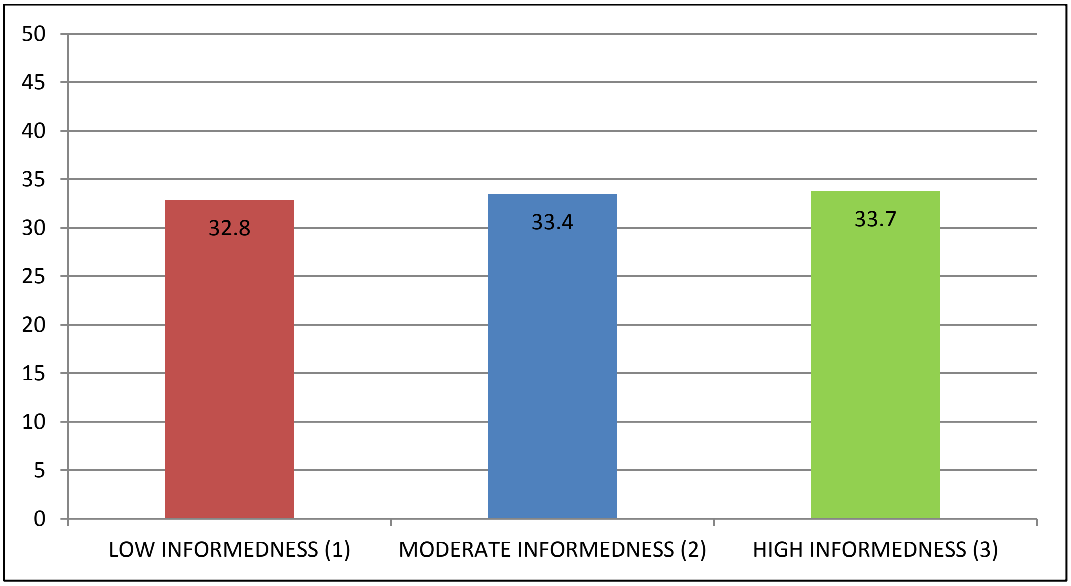


Chart 11.4 *Index of Informedness about Science* overall national result (2015)

As noted in the earlier section, rates of informedness would lag rates of interest in science, as a result of the relationship between these variables (to be discussed). These results were earlier discussed in Chapter Five, wherein overall informedness was recorded at lower proportions compared to level of interest within this sample. That being said, over all, 67.2% of respondents within this survey report a *moderate* to *high* level of informedness regarding science. This is an encouraging outcome, despite the similarly high level of respondents being classified as possessing a *low* level of *informedness* with respect to science.

11.2.5 *Scientific Information Immersion Index*

Response within the sources of science information question set is used in the development of the Scientific *Information Immersion Index*. As discussed in Chapters Four and Nine, items included span a wide array of technologies, media channels and information sources. Response categories ask respondents to indicate the frequency of encountering science related information from each of the 11 items in the information source column (see table 11.15)

INFORMATION SOURCE	Most Frequently	Frequently	Least Frequently
Satellite Pay Television (DSTV, TopTv)	1	2	3
Free-to-Air Television (SABC / E-Tv)	1	2	3
Radio	1	2	3
Newspapers	1	2	3
News Websites	1	2	3
Institutional Websites (University / Research Lab)	1	2	3
Government Announcements	1	2	3
Blogs	1	2	3
Social media (Facebook, Twitter)	1	2	3
Other people (Family, Friends, Colleagues)	1	2	3
Books / Magazines	1	2	3

Table 11.15: Information sources about science assessment question set

From these 11 items, a measure was established that provides an assessment of respondent *immersion* in scientific information channels. This was achieved through developing an assessment of the *count* and *frequency* of encountering information via the selected information sources. Responses to the question set were recoded to allow for the creation of a *SUM InfoSource* variable. Recoding involved applying the highest code to the *most frequently category* (3), followed by *occasionally* (2) and *least frequently* (1). All *don't know* response was classified as invalid and not used within the construction of the *SUM InfoSource* variable nor the index. Within the sample of 3 486 respondents, 257 individuals selected an invalid response, thus yielding a final valid response equal to 92.6% (3 229). Within this revised coding and scoring system, the maximum *SUM InfoSource* score achievable across the 11 items was 33 while the lowest valid score was 1. Various mathematical operations were attempted to reduce the *SUM InfoSource* maximum value from 33, to a value that would be less demanding to communicate. However, many of the solutions, while successful, offered little additional value to the actual index and introduced cumbersome categories for cut-off points, as a result the original scoring range was retained.

	SUM INFO SOURCE SCORE ACROSS 11 ITEMS	Frequency Count	% (VALID)
VALID	**33**	**28**	0.9%
	32	**9**	0.3%
	31	**19**	0.6%
	30	**22**	0.7%
	29	**23**	0.7%
	28	**40**	1.2%
	27	**51**	1.6%
	26	**59**	1.8%
	25	**70**	2.2%
	24	**88**	2.7%
	23	**96**	3.0%
	22	**124**	3.8%
	21	**100**	3.1%
	20	**119**	3.7%
	19	**132**	4.1%
	18	**151**	4.7%
	17	**153**	4.7%
	16	**172**	5.3%
	15	**216**	6.7%
	14	**153**	4.7%
	13	**203**	6.3%
	12	**122**	3.8%
	11	**353**	10.9%
	10	**71**	2.2%
	9	**70**	2.2%
	8	**75**	2.3%
	7	**64**	2.0%
	6	**99**	3.1%
	5	**72**	2.2%
	4	**65**	2.0%
	3	**97**	3.0%
	2	**70**	2.2%
	1	**43**	1.3%
INVALID	0	257	7.4%
	VALID	**3229**	**100.0%**
	TOTAL	3486	

Table 11.16: Information sources about science: *SUM infosource* score distribution

Following consultation with the research supervisor, and minor changes to the index construction, akin to those in the previous sections, the final index output design and response is presented in table 11.17. Respondents with a *SUM InfoSource* score of between 1 and 11 were classified as the *low information immersion* group; those with a score of 12 to 17 were categorised as the *moderate information immersion* group while respondents scoring between 18 and 33 were classified as the *high information immersion* group. These index categories represent the *count* and *frequency* of science information sources accessed by the respondents, with increasing counts and frequencies attaining higher scores within the final scoring solution.

	SUM INFO SOURCE (score across 11 items)	FREQUENCY	CLASSIFICATION GROUP	COUNT PER GROUP	valid % PER GROUP
VALID	33	28	HIGH	1131	35.0%
	32	9			
	31	19			
	30	22			
	29	23			
	28	40			
	27	51			
	26	59			
	25	70			
	24	88			
	23	96			
	22	124			
	21	100			
	20	119			
	19	132			
	18	151			
	17	153	MODERATE	1019	31.6%
	16	172			
	15	216			
	14	153			
	13	203			
	12	122			
	11	353	LOW	1079	33.4%
	10	71			
	9	70			
	8	75			
	7	64			
	6	99			
	5	72			
	4	65			
	3	97			
	2	70			
	1	43			
		3229			
		3486			

Table 11.17: Scientific *Information Immersion Index*

Within the *Scientific Information Immersion Index* respondents are classified on a 3-level outcome in response to their total *SUM InfoSource* score.

Index Data Output and Analysis

The *Scientific Information Immersion Index* demonstrates a pattern of broad distribution regarding science information immersion behaviours within the total sample. Overall a marginally larger share of respondents were classified as having *high information immersion* (35.0%), while 31.6% report a *moderate* level and 33.4% display tendencies toward a *low* information immersion classification. This indicates that within the *high information immersion* group, 35.0% of respondents accessed a greater number of information channels and had done so at a greater frequency.

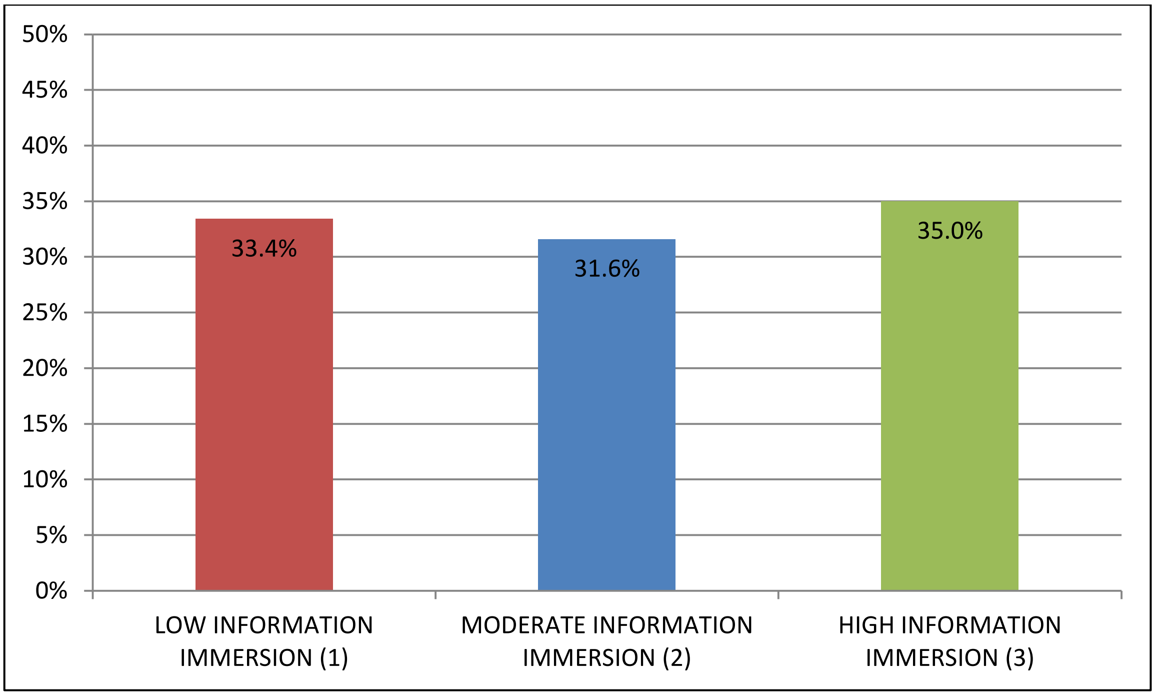


Chart 11.5: *Scientific Information Immersion Index* overall national result (2015)

The *high information immersion* group was comprised of 1 131 respondents. Among these individuals 22.2% reported encountering science information via more than 8 different channels *most frequently*. The majority of people within this group (77.8%) report encountering science information through between 6 and 8 different channels *most frequently*. The *moderate information immersion* group contained 1 019 respondents and 53.1% of these individuals report an average of between 5 and 6 science information channels with a frequency ranging between *occasionally* and *most frequently*. The remainder of this group (46.9%) was made up of individuals whom had reported between 4 and 5 science information sources within the same frequency range as previously mentioned. The *low information immersion* group classified 1 079 respondents, with 58.7% of these encountering science information from between 2 or 3 information channels *least frequently* or occasionally. While the remaining 41.3% of individuals within this group encountered science information from between 1 and 2 information sources at a very low *frequency*.

11.2.6 *Index of Science Engagement*

Data from the science engagement question set was adopted in the development and construction of the *Index of Science Engagement*. This question set asked respondents to indicate if they had visited one of the science engagement locations within the preceding 12 month period (see Chapter Four and Chapter Ten). Response was captured through a single selection of *yes*; *no* or *don't know* options (see table 11.18).

SCIENCE ENGAGEMENT ACTIVITIES	YES	NO
Public Library	1	2
Zoo or Aquarium	1	2
Museum (any)	1	2
Science Centre, Technology exhibition	1	2
Science Fair, Festival or similar Public Event	1	2

Table 11.18: Science engagement question set

Minimal recoding was applied to this question set toward the development of a *SUM engaged* variable. All *don't know* and *no* responses were considered *invalid* and not considered in the development of the *SUM engaged score*. Among all respondents, 2 536 individuals reported an invalid response and these were not included in the development of the index structure. All valid responses received a score of 1 and allowed SPSS to compute the *SUM engaged* variable across all 5 items for each respondent. The *SUM engaged* score had a range from 1 to a maximum of 5.

	SUM ENGAGEMENT SCORE ACROSS 5 ITEMS	Frequency Count	% (VALID)
INVALID	0	2536	
VALID	1	458	13.1%
	2	224	6.4%
	3	126	3.6%
	4	70	2.0%
	5	72	2.1%
	TOTAL	**3486**	**27.3%**

Table 11.19: *SUM engagement* score distribution

An initial index classification system was revised following review in favour of an empirically driven classification system. The final index classification ranking was based on 33% percentile cut-offs where respondents reporting attendance at 1 engagement activity was classified as *low engagement*; those attending 2 engagement activities were classified as *moderate engagement* and those attending between 3 and 5 activities within the reference period were classified within the *high engagement* group. The final index classification and response frequencies are presented in table 11.20 below.

	SUM ENGAGEMENT SCORE	FREQUENCY	COUNT PER GROUP	valid % PER GROUP
COUNT OF ACTIVITIES ATTENDED	1	458	LOW	48.2%
	2	224	MODERATE	23.6%
	3	126	HIGH	28.2%
	4	70		
	5	72		
	VALID	**950**	**27.3%**	
	TOTAL	**3 486**		

Table 11.20: *Index of Science Engagement*

As a result of the low levels of reported *science engagement*, the decision to include 3 or more visits to any of the listed locations as *high engagement* is supported by the data as it appears South Africans in general do not regularly visit these locations. This may change with future research, however, is acceptable within the current exploratory study framework.

Index Data Output and Analysis

A key finding within this study is that the vast majority of South Africans do not attend science engagement activities regularly. Among the total sample of 3 486, 72.7% of respondents reported a *no* or *don't know* response, though invalid in terms of the index, still represents an interesting finding from this research.

Among the 950 individuals that reported attendance at a minimum of one science engagement activity within the reference period, the vast majority of these were classified within the low category (48.2%).

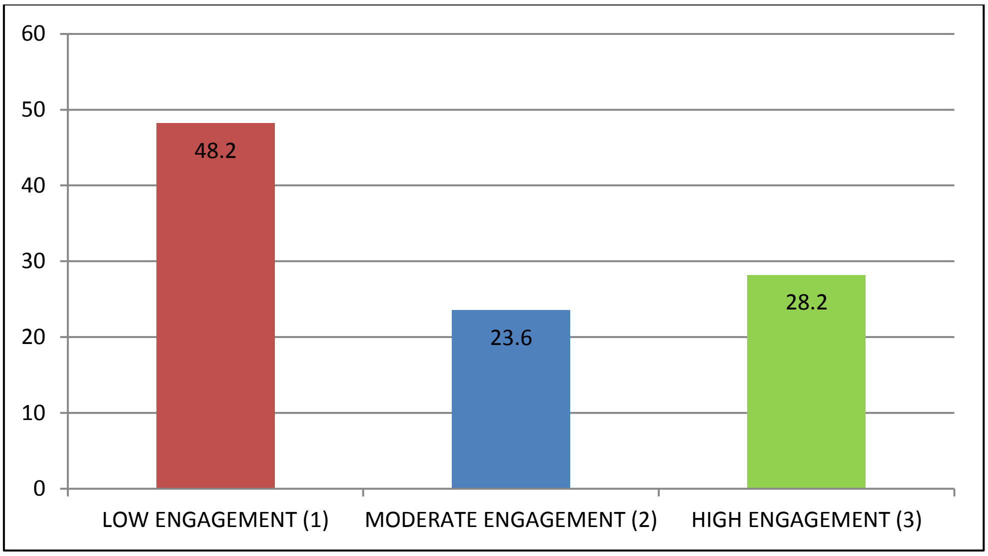


Chart 11.6: *Index of Science Engagement*: overall national result (2015)

Respondents reporting 2 visits to science engagement activities were classified within the *moderate* engagement group (23.6%), while 28.2% indicated more frequent attendance and were thus classified within the *high* science engagement grouping.

11.2.7 Assessment of Relationships between SAPUS Indicators

An analysis was undertaken to assess the strength and direction of any relationships that may exist between the six indicators produced. The potential for relationships between the indicators is analysed using the *Pearson product–moment* correlation, which provides reliable estimations as to the degree to which a linear predictive relationship exists between the various outputs of this research. Within the correlation outputs, if a relationship exists between the indicators, the correlation would tend toward a value of 1.00 (or -1.00). If no relationship exists the correlation value would equal 0.00. A positive value for the correlation is indicative of concurrent increases in both variables – *as the outcome on one indicator changes so does the outcome on the other*. The presentation of a negative correlation value would yield the inverse relationship wherein *increases in one indicator may be indicative of decreases in the other* (Wilson *et al,* 2007).

Establishing the existence of relationships between the six indicators remains important toward demonstrating additional reliability within the measures while also contributing to the overall validation of the metrics produced.

Among the six indicators produced, five demonstrated weak positive correlations among each of them, while one indicator demonstrated negligible coefficient value to only a single indicator. While it is not expected that all indicators would demonstrate very strong relationships between them, it is expected that positive associations would be demonstrated among these theoretically related measures.

The *science knowledge index* demonstrated weak positive relationships with the *Interest* (0.120**); *informedness* (0.122**); *info-source* (0.147*) and *engagement* (0.081*) indices. All of these correlations, while they may be considered negligible, are none-the-less positive and have been found to be statistically significant.

No significant association was found between the *knowledge index* and the *attitudinal index*; however, this has long been supported within the literature and was not entirely surprising (Evans and Durant, 1995; Aminrad, *et* al, 2013). The *index of attitudes* to science was not correlated with any of the remaining five indices produced. A very weak association with the *informedness index* was found to be statistically significant, however at the 0.045 value would in most cases be considered a negligible correlation outcome.

		KNOWLEDGE INDEX	ATTITUDE INDEX	INTEREST INDEX	INFORMEDNESS INDEX	INFO SOURCE INDEX	ENGAGEMENT INDEX
KNOWLEDGE INDEX	**Pearson Correlation**	**1.00**	0.009	**.120****	**.122****	**.147****	**.081***
	Sig. (2-tailed)		0.631	**0.000**	**0.000**	**0.000**	**0.014**
	N	3188	3105	2512	3106	3021	906
ATTITUDE INDEX	**Pearson Correlation**	0.009	**1.00**	-0.030	**.045***	0.000	-0.005
	Sig. (2-tailed)	0.631		0.128	**0.011**	0.991	0.868
	N	3105	3311	2584	3223	3127	936
INTEREST INDEX	**Pearson Correlation**	**.120****	-0.030	**1.00**	**.537****	**.352****	**.172****
	Sig. (2-tailed)	**0.000**	0.128		**0.000**	**0.000**	**0.000**
	N	2512	2584	2640	2624	2531	875
INFORMEDNESS INDEX	**Pearson Correlation**	**.122****	**.045***	**.537****	**1.00**	**.479****	**.196****
	Sig. (2-tailed)	**0.000**	**0.011**	**0.000**		**0.000**	**0.000**
	N	3106	3223	2624	3346	3141	938
INFO SOURCE INDEX	**Pearson Correlation**	**.147****	0.000	**.352****	**.479****	**1.00**	**.203****
	Sig. (2-tailed)	**0.000**	0.991	**0.000**	**0.000**		**0.000**
	N	3021	3127	2531	3141	3229	907
ENGAGEMENT INDEX	**Pearson Correlation**	**.081***	-0.005	**.172****	**.196****	**.203****	**1.00**
	Sig. (2-tailed)	**0.014**	0.868	**0.000**	**0.000**	**0.000**	
	N	906	936	875	938	907	950

** Correlation is significant at the 0.01 level (2-tailed)* Significant at the 0.05 level (2-tailed).(Info-Source = information immersion index)

Table 11.21: *Correlation* between 6 SAPUS indicators

With the exception of the *attitude index*, the *index of interest* in science was positively correlated with the *knowledge* (0.120**); *informedness* (0.537**); *info-source* (0.352*) and *engagement* (0.172*) indices. The association between scientific interest and scientific informedness, while theoretically expected, presented the highest correlation value among all indicators. This value indicates a moderate positive two-way relationship between these variables. Definitive causality cannot be established within this analysis; however the existence of this strong association highlights a significant finding. A similar relationship, albeit weaker than the aforementioned, does exist between interest and the information source indicator, while between the interest and engagement indices, a weak, though positive association exists.

The relationships between the *informedness index* and the *knowledge*, *interest* as well as *attitude* indices have already been addressed. A significant association was found between the *informedness* *index* and the *information immersion index* (0.479**) as well as the *science engagement index* (0.196**). The association between the *informedness index* and the *information immersion index*, while not unexpected demonstrates a similarly moderate positive association between these indicators. The *science engagement index*, while being addressed above in its relationships to the other indicators, was positively associated with the *information immersion index* (0.203**). While many of these associations are below the level of 0.300, and may be considered weak the positive relationship between the variables is none the less an encouraging pattern within this exploratory research, producing an indicator series to measure the South African public understanding of science.

11.2.8 Segmenting the South African PublicS

Segmentation refers to the practice of organising people into uniform groups, based on a set of defined input criteria (Cirksena and Flora, 1995). Segmentation has been advanced within the commercial research environment toward the production of *audience* or *market* segmentation models that offer business or media channels the most accurate picture of whom their target consumers are and how best to serve their needs. While the purpose of segmenting a consumer base is essentially a *discriminatory* practice – intended to illuminate need so as to best *serve* those needs – within the public sector space this often raises multiple ethical considerations. Research and eventual segmentation related to health promotion, public services and party-political campaigns often attract unintended controversy regarding the methodological and moral implications of targeted informational segments, and the exclusion of other general public segments (Gruber and Caffrey, 2005).

The practice of audience and public segmentation has tremendous value within public sector research and may offer greater efficiency toward responding to the multitude of important social questions in addressing research and service delivery. It is however essential to reframe the *discriminatory* facet of segmentation practice when transposing these techniques into the area of *public focused* research. Particularly within this public engagement space, the requirement remains not to separate the public in order to *discriminate*, but rather to *recognise diversity in order to enhance* inclusivity (Barnett and Mahony, 2011).

Segmentation techniques rely on multiple data inputs toward effectively *discovering* or *developing* realistic representations of the general public within a data model. As the result of this segmentation is often a time consuming, costly and *inherently risky* endeavour, leading to various categories of segmentation outputs. The *inherent risk* relates to the *trust investment* required toward policy and operational system adjustment based on these models that are *theoretically* designed to highlight and best serve the given *public segments* of concern. Where the implications and consequences of poor planning requires a vigilant approach, the significant resources invested into the development of accurate and reliable segmentation accounts for this risk. On the other hand, within lower risk applications, as an exploratory technique, segmentation also offers the ability to better understand specific target audience profiles within an iterative approach of ongoing refinement. This has particular value within emerging fields such as science communication for the South African context. The earlier noted diversity and commonalities among South African society requires targeted approaches of communication and science policy implementation directed at specific areas and publicS within the broader South African population.

Segmentation employed various techniques to arrive at specific public profiles or audience characteristics. These may include *demographic* variables such as *race, age, education, gender* or *geographic location*. Similarly, classification may employ the use of *behavioural* information (information seeking, media usage etc.) or an emerging area of *psychographic* variables. These *psychographic* variables include areas of *beliefs*, *feelings*, *attitudes* and shifting patterns of opinion particularly with respect to a variety of public sector topics (Barnett and Mahony, 2011).

Within the dataset discussed in this research, a *general* segmentation approach was adopted to *describe*[140] potential groupings within the sample regarding their general public understanding and engagement with science. Data for the variables *interest, informedness, knowledge, information immersion, attitude to scien*ce and *science engagement* were considered within the development of the segmentation process. As a result of the degree of interrelatedness as well as the *behavioural* and *practical* implications attached, respondents were initially segmented into classifications using their response to the *interest, informedness* and *knowledge* indices. These were selected by adopting a generalised linear decision making process: *greater reported interest leading to information seeking behaviour* (toward building informedness) *and demonstrating this through outcomes on knowledge assessments*. Respondents were then segmented based on their performance on these *interest, informedness* and *knowledge* assessment outcomes into four segments to be discussed below. Characteristics for *attitude* and *engagement* were later included.

[140] Rather than *discover* particular audiences– targeted segmentation requires clearly defined strategic purposes related to specific outcomes, within this sense, the purpose here is to demonstrate what is possible through a *general* segmentation, rather than produce a definitive specific segmentation model

SEGMENT NAME	%	SEGMENT CHARACTERISTICS
NON-ENGAGERS	**31.3%**	LOW INTEREST, INFORMEDNESS, KNOWLEDGE, NEGATIVE ATTITUDE
CASUALLY INTERESTED	**21.0%**	LOW-MODERATE INTEREST, INFORMEDNESS, KNOWLEDGE, NEGATIVE – AMBIVALENT ATTITUDE
CAUTIOUS OPTIMISTS	**19.4%**	MODERATE-HIGH INTEREST, INFORMEDNESS, KNOWLEDGE, POSITIVE-AMBIVALENT ATTITUDE
ACTIVE ENGAGERS	**28.3%**	HIGH INTEREST, INFORMEDNESS, KNOWLEDGE, POSITIVE ATTITUDE

Table 11.22: Proposed South African Public Understanding of Science segmentation groups

Table 11.22 presents the proposed public segmentation from within the data in this research. It is important to note that while the clusters represent respondents who share similar *interest*, *informedness*, *knowledge* and *attitudes* regarding science, not all respondents included in each group are identical. This remains common practice within exploratory segmentation outputs and a consequence the produced segments are *illustrative typologies*, rather than exact representation of every member within that segment (BIS, 2011).

The *Non-Engagers* are the largest cluster making up 31.3% of respondents within this survey. These respondents generally demonstrate lower levels of scientific interest, informedness and *scientific knowledge*, compared to other groups. They similarly display attitudes that are more critical of science and are least likely to believe in the contribution of science to society. Less than 2% of respondents within this category have attended a science engagement activity within the preceding 12 month period. *Non-Engagers* tend to be non-white, mostly from within the black, coloured or Indian / Asian sub-samples and predominantly female. These individuals also tend to predominantly reside within rural areas, are older than 50 years old and have a pre-matric educational attainment level. These respondents are often unemployed and therefore have a low household income level.

The *Casually Interested* represents about 1 in 5 respondents within this sample (21.0%). They usually present a *low* to *moderate* level of *interest*, *informedness* and *scientific knowledge*. They tend to be interested in science; however, do not often report being highly informed or demonstrate higher levels of scientific knowledge. The *casually interested* present attitudes that are *negative* to *ambivalent* and while they do appreciate scientific advances, they remain sceptical about the value science may add to *their* contemporary and future experiences. This segment contained the largest proportion of respondents within the coloured sub-sample with an even distribution of males and females. They tend to be aged between 20 and 49 years old and generally have not had exposure to post-matric education. The majority report being *unemployed* or *other (not working)* leading to low or moderate household income within this segment.

Cautious Optimists account for 19.4% of response within the survey. These individuals present *moderate* to *high interest, informedness* and levels of *scientific knowledge*, compare to previous segments. While their attitudes tend to be more positive about science, they do possess a degree of ambivalence regarding the value of science to society. Respondents within this segment tend to strongly support the promise of scientific advancement while maintaining a cautious awareness of the ways in which technology influences their lives. The majority of these respondents tend to be females located within the urban centres and are largely from within the coloured and white population groups. *Cautious optimists* are generally younger than 39 years old and possess a completed matric or higher educational qualification. These individuals are mostly employed, retired, involved in domestic or academic activities and report a *moderate* to *high* household income. An average of 11.4% of respondents within this segment has attended a science engagement activity within the reference period, not differentiated from the national average.

The segment with the highest overall reported level of interest, informedness and *scientific knowledge* are the *Active Engagers* (28.3%). These respondents generally have very positive attitudes to science, strongly supporting the promise of science and its value to future South Africans. The greater part of this segment tends to be white, urban males below the age of 30 years. These respondents generally have a post-matric educational attainment level, are employed and report a high level of household income. On average, 29% of *active engagers* report attending at least one science engagement location within the preceding 12 month period. Members of this group report that approximately 40% have visited a *public library* while more than 20% have visited a *zoo, aquarium* or *museum* within the reference period.

The above *empirically derived* segmentation *proposal* presents what is possible and what has till this point not been attempted within the South African scholarly contributions to the public understanding of science. It must be noted that this remains a *proposal* and greater confirmatory effort must be invested toward specific strategically relevant segmentation frameworks. However, as a general segmentation model of the overall South African public, the above presents a useful point of departure. Adopting a targeted communication and engagement facilitation approach would introduce greater efficiencies and enable the diversion of critical resources to the areas of greatest investment need. Science communication, science policy and the academic polemic within *scientific literacy* and the *public understanding of science*, as interdisciplinary areas must meaningfully adapt solutions that would best serve to deliver the essential information and research that will drive effective evidence based decisions influencing the public relationship with science. Reversing the discussion from *public understanding of science*, to *understanding who the public are*, may represent the most useful undertaking along that journey.

11.3 PREDICTORS OF OUTCOMES ON SAPUS INDICES

As discussed in the introductory chapters to this thesis (Chapter One and Chapter Two), South Africa is a country of diverse and multicultural backgrounds all seated within a legacy of separate development as a result of the apartheid past. As a direct result of this, *sociodemographic* variables exert a dramatic influence on individuals' access to services, resources and various other variables that have been demonstrated to influence respondent outcomes on the six elements of the South African public understanding of science. In order to provide a holistic evaluation of the South African general public understanding of science it remains important to determine which sociodemographic variables may best serve as *predictors* of outcomes within each indicator. This would provide an appraisal of the most influential factors determining respondent performance on each indicator toward highlighting the impact of these predictors in relation to the various indices produced. This research question will be addressed within this sub-section toward highlighting the influence of the most salient sociodemographic predictors influencing the general South African public understanding of science.

Regression analytics was identified as the most suitable tool to adopt in responding to this research question. This analytical tool is useful in identifying relationships among a set of *independent* (predictor) variables and an *outcome* variable and is widely used in *prediction* and *forecasting* analysis (Long and Freese, 2001). A generalised regression equation would infer the following:

$$Y = a + bX$$

Where Y = Outcome variable (dependant variable)
a = Intercept (value of Y where X = 0)
b = slope (change in Y per unit change in X)
X = unknown parameter

Each of the six indicators produced has been considered as a *dependant* variable within this analysis, while each of the sociodemographic predictors have been considered as *independent* variables. As a result of each of the index outcome variables being *polytomous* – i.e. having more than one outcome possibility[141], an extension to the standard regression model is required that would be best equipped to produce the analysis. As such m*ultinomial logistic regression* was identified as the most suitable analytic tool to perform this analysis as it has become the benchmark tool to identify and describe relationship between *response* and *explanatory* variables, within these conditions (Agresti, 2007). *Multinomial Logistic Regression* has become the standard analysis (among other more specialised techniques), for efficiently identifying and interpreting outputs of relationships between variables in a wide-array of fields including engineering, social research, risk analysis, medicine and numerous other research areas (Bayaga, 2010). The basic deviation from standard regression analysis involves the multiple levels of outcomes within the response variable (dependant variable). As such multinomial logistic regression models the probability of responses appearing within the outcome levels of Y (response variable) as a result of the influence of a set of explanatory variables. This is achieved through the production of a series of probability estimates based on the influence of the predictor variables and is represented as a function of *the probability of appearing within one level of the outcome variable, compared to the reference category.* According to Agresti (2007) the selection of the reference category is *arbitrary*. A generalised representation of the multinomial logistic regression is presented in image 11.1 below.

$$\log\left(\frac{\pi_a}{\pi_b}\right) = \log\left(\frac{\pi_a/\pi_J}{\pi_b/\pi_J}\right) = \log\left(\frac{\pi_a}{\pi_J}\right) - \log\left(\frac{\pi_b}{\pi_J}\right)$$
$$= (\alpha_a + \beta_a x) - (\alpha_b + \beta_b x)$$
$$= (\alpha_a - \alpha_b) + (\beta_a - \beta_b)x$$

Image 11.1: Generalised multinomial logistic regression equation (Agresti, 2007)

The outputs of the multinomial logistic regression provides insight into the probability, or *odds* of an outcome occurring, given a particular set of predictor attributes as a measure of association between the *outcome* and *predictor* variables within the model (Long and Freese, 2001).

Each of the six indices within this study has undergone a similar analytic procedure, which will be described to avoid duplication. This will be followed by the presentation of the outputs from this analysis. The procedures and analysis within this section was largely influenced by the early work of Laugksch (1996) and is guided methodologically by the work of Long & Freese (2001) and Agresti (2007). Statistical output and interpretation within this section was assessed by senior statisticians at the HSRC to ensure their accuracy and reliability of the results obtained[142].

[141] As an example – the *Knowledge Index* has 3 outcome levels – *High*, *Moderate* and *Low*
[142] Specific appreciation is extended to Dr Moses Sithole for his invaluable input into this section

As described in the earlier chapters this survey collected information from 3 486 valid respondents using a 6-question, 43 item research instrument. Selected items within this instrument were adopted, following rigorous statistical quality assurance procedures toward the development of six indices, measuring the defined elements of the South African public understanding of science. The indices developed have been used as the *dependant variables* within this analysis and are again presented in table 11.23 below.

INDICATOR (Outcome variable)	Valid N	Cronbach's Alpha	Mean	Standard Deviation	Coding
Science knowledge index	3188	0.911	1.99	0.85	1= Low; 2 = Moderate; 3 = High
Attitudes to science index	3311	0.939	0.25	0.76	-1= Negative; 0 = Ambivalent; 3 = Positive
Interest in science index	2640	0.936	2.00	0.81	1= Low; 2 = Moderate; 3 = High
Informedness in science index	3346	0.949	2.01	0.82	1= Low; 2 = Moderate; 3 = High
Information immersion index	3229	0.946	2.02	0.83	1= Low; 2 = Moderate; 3 = High
Science Engagement index	950	0.943	1.80	0.85	1= Low; 2 = Moderate; 3 = High

Table 11.23: Six indices developed to be used as dependant (outcome) variables

The development, validation and result within each index have been discussed within this chapter and will not be repeated here. Table 11.23 however presents the overall quality and reliability statistics for each indicator as well as the coding system adopted within the final index construction.

An initial purposive selection of 12 sociodemographic variables was considered as predictors of outcomes for each indicator. Coding, variable characteristics and descriptive statistics are provided in table 11.24 below.

Sociodemographic Predictors	Valid N	Mean	Standard Deviation	Coding
DEMOG_RELIGION	3486	4.70	4.27	1-14 Categories for all major religions; Other; None and D/K (see appendix table)
DEMOG_MARITAL_STATUS	3486	1.77	0.99	1 = single; 2 = married; 3 = cohabitation; 4 = widowed; 5 = Divorced; 6 = separated
DEMOG_PERSONAL_INCOME	3486	24.82	10.08	same as *Household Income*
DEMOG_POP_GROUP	3486	2.17	0.79	1 = White; 2 = Black; 3 = Indian / Asian; 4 = Coloured
DEMOG_PROVINCE	3486	5.24	2.50	1 - 9: All provincial areas (see appendix table)
DEMOG_RURAL_URBAN	3486	1.34	0.47	1 = Urban; 2 = Rural
DEMOG_GENDER	3486	1.50	0.50	1 = Male; 2 = Female
DEMOG_AGE	3472	3.21	1.34	6 age categories from <20 years to 60 years + (see appendix table)
DEMOG_LANGUAGE	3486	6.40	3.87	12 language categories, including Other category (see appendix table)
DEMOG_EDUCATION	3486	1.76	0.70	1 = Pre-matric; 2 = Matric completed; 3 = Post-matric
DEMOG_EMPLOYMENT	3486	1.74	0.75	1 = Employed; 2 = Unemployed; 3 = Other (not working)
DEMOG_HH_INCOME	2271	1.35	0.60	1 = Low income; 2 = Moderate income = 3 = High income (see appendix table)

Table 11.24: Sociodemographic variables considered for modelling of predictors

With due consideration for issues related to model stability as a result of the number of predictors included in the analysis, a data reduction strategy was employed to ascertain the variables offering the maximum predictability and reliability within the outcome estimations. The recommendations of

Agresti (2007) and Long & Freese (2001) were adopted toward reducing the number of potential predictors from 12 to 8. To avoid complications as a result of *multicollinearity* and *singularity* within the regression analysis, relating to the contribution of each variable as well as the degree of correlation between those included, variables were excluded from the available set for use within the regression analysis. *Univariate* and *bivariate* analysis (see chapters five through ten) indicated that the variables for *religion; marital status; personal income* and *province* would not offer additional explanatory value and were no longer considered within the multinomial regression analysis.

Following further initial regression analysis it was found that the *language* group variable was similarly confounding the output as a result of its association with race and other variables and was subsequently removed from further analyses. The final list of potential sociodemographic predictor variables then included 7 items *race; rural-urban location; gender; age group; education; employment status* and *household income*.

The multinomial logistic regression was performed using IBM-SPSS (version 24) adopting the following procedure. Within the *regression* options in SPSS, the option for multinomial logistic regression was selected. The outcome variable (*SAPUS index*) was included as the *dependant variable* field, while all 7 sociodemographic potential predictor variables were input into the *factors* field. Within the dependant variable the *reference* category selected was the *first* code (*low* in most indices) while the reference category for the *independent* variables (predictors) was automatically set to be *last* by SPSS. This is not changeable and where required coding adjustment would be reported to account for any impact this may have. The model selected for the processing of the regression was a *custom stepwise* model to assess *main effects* within each potential predictor variable. A *backward-elimination-stepwise* method was employed as this allowed for the initial inclusion of all variables, and through a testing procedure deleting any variable that does not statistically improve the model's predictive accuracy. This procedure ensures that the final model included only the predictor variables with the highest predictive value within the model. The same procedure was applied for the analysis of each of the six indices and where any variations were introduced these will be highlighted in the appropriate sub-sections to follow. The results of the multinomial logistic regression are consistent with the chi-square analysis presented earlier in this chapter (indicators results).

Predictors of outcomes on the *Science Knowledge Index* (SKi)

The multinomial logistic regression model of predictors of outcomes on the *Science Knowledge Index* is based on a valid response of 2 041 respondents as a result of *case-wise* deletion due to selected cells containing zero frequencies[143] (L: 101.678; $d.f.$ = 14; p < 0.001). Among the seven potential variables included within the analysis, six were retained following the output of the *step-wise multinomial logistic regression* procedure. The four variables that were eliminated include: *age; employment status; rural / urban location* and *gender*. These variables were excluded based on the value of the chi-square achieved within the *likelihood ratio test*, all of which were found not be statistically significant. The result for the *model fitting information, goodness-of-fit* and *likelihood ratio test* are presented in table 11.25. The model fitting information demonstrates a significant chi-square and *p*-value, indicating that the retained variables significantly improve the overall model, compared to the *intercept-only* model.

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1931.190			
Final	1829.512	101.678	14	0.000

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	1000.608	1044	0.829

Likelihood Ratio Tests				
Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1829.512	0.000	0	
DEMOG_RACE	1842.536	13.024	6	0.043
DEMOG_EDUCATION	1849.143	19.631	4	0.001
DEMOG_HH_INCOME	1860.721	31.209	4	0.000

Table 11.25: Model fitting information, goodness-of-fit and likelihood ratio test

An assessment of the *goodness-of-fit* information reveals how well the model fits the observed data within the study. The *p-value* indicates a value greater than 0.05, demonstrating that the model fits the data well due to the predicted values not being significantly different from the observed values

143 Due to the manner of calculation, the NOMREG (multinomial logistic regression) procedure in SPSS calculated cells based on the 3 category outcome variable and populates this as a contingency table for each category within the predictor variables. Sub-populations may as a result have a zero frequency (0), where SPSS deletes the entire case from within the analysis. Important to note this is not missing data, but due to the NOMREG calculation process.

in the data set. The variables retained within the model are presented within the *likelihood ratio test* and include: race*; educational attainment* and *household income* as a result of their statistically significant *p-value* (see table 11.25).

In table 11.26, for each of the variables statistically significant within the model the following information is presented: A) the slope coefficient; B) the standard error C) the odds ratio and D) the 95% confidence interval for the odds ratio. Within the initial table all three variables produced a unique contribution to the overall model. The influence of race demonstrates the strongest predictive value within the model (B = -1.214; Wald= 9.18; p < 0.01). This is demonstrated where respondents within the Indian / Asian group are only 29.7% as likely as coloured respondents (reference category) to appear within the *moderate scientific knowledge* group, compared to the *low scientific knowledge* group. With the adjustment of the race variable *reference* category to the *white* sub-sample, members of the Indian / Asian sub-sample are 42.0% as likely to appear in the *moderate* group (compared to the *low* group) when compared to white respondents (not in table). This result is in further agreement with earlier presented scientific knowledge index findings, where white and Indian / Asian respondents were significantly more frequently represented within the *high* scientific knowledge group compared to other race classifications.

	Predictor	B	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
Moderate compared to Low knowledge	DEMOG_RACE - White (1)	-0.348	0.284	0.706	0.405	1.231
	DEMOG_RACE - Black (2)	-0.347	0.206	0.706	0.472	1.058
	DEMOG_RACE - Indian / Asian (3)	-1.214	0.401	**0.297**	0.135	0.651
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.542	0.205	**0.582**	0.389	0.870
	DEMOG_EDUCATION - Moderate (2)	0.014	0.185	1.014	0.706	1.456
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_HH_INCOME - Low (1)	-0.854	0.304	**0.426**	0.235	0.772
	DEMOG_HH_INCOME - Moderate (2)	-0.409	0.294	0.664	0.373	1.183
	DEMOG_HH_INCOME - High (3)	Reference	Reference	Reference	Reference	Reference

	Predictor	B	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
High compared to Low knowledge	DEMOG_RACE - White (1)	0.085	0.261	1.089	0.653	1.815
	DEMOG_RACE - Black (2)	-0.206	0.195	0.814	0.555	1.193
	DEMOG_RACE - Indian / Asian (3)	-0.404	0.320	0.668	0.357	1.250
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.124	0.188	0.883	0.611	1.276
	DEMOG_EDUCATION - Moderate (2)	-0.016	0.172	0.985	0.702	1.380
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_HH_INCOME - Low (1)	-1.166	0.276	**0.312**	0.181	0.535
	DEMOG_HH_INCOME - Moderate (2)	-0.481	0.265	**0.618**	0.368	1.039
	DEMOG_HH_INCOME - High (3)	Reference	Reference	Reference	Reference	Reference

Table 11.26: Scientific Knowledge Index Parameter estimates (Reference category: Low knowledge)

The *educational attainment* variable indicates that respondents in the *low* education group were only 58.2% as likely as respondents in the *high* education category to appear in the *moderate scientific knowledge* classification compared to the *low knowledge* classification (B = -0.542; Wald= 6.958; $p < 0.01$). Where the reference group for education is shifted from the *high* group to the *low* education group, both those with moderate and high educational attainment levels are 1.7 times more likely to appear in the moderate scientific knowledge group than the low scientific knowledge classification group, compared to respondents with *low educational attainment*. This reinforces the tremendous role education plays within science knowledge and ranking within the *scientific knowledge index*.

Household income was significantly associated both within the *moderate* and the *high* knowledge parameter estimate tables. The influence of household income is observed, wherein respondents with *low* reported household income are only 42.6% as likely as those within the high income group to appear in the *moderate scientific knowledge* group, compared to the *low scientific knowledge* group (B = -0.854; Wald= 7.902; $p < 0.01$). Similarly, respondents within the *low income group* were only 31.2% as likely as *high income* earners to appear in the *high scientific knowledge* group, compared to the *low scientific knowledge* group (B = -1.116; Wald= 17.853; $p < 0.001$). Further reinforcing the influence of *household income*, respondents within the *moderate* income category were found to only be 61.8% as likely as *high* income earners to appear in the *high* knowledge classification compared to the *low* knowledge group. As reported within the index results, the influence of *household income* has a significant determining influence on performance, where more often, respondents from higher income households, present a higher outcome ranking on the *science knowledge index*.

These results confirm the outcomes presented in the initial part of this chapter and highlight race, education and household income as the key demographic variables influencing outcome on the *scientific knowledge index*. Considering the interrelations between race, education and income within the South African context this result is not entirely unexpected and highlights the sociodemographic areas of potential intervention toward increasing scientific knowledge among the population. Accordingly, the multinomial logistic regression model representing the *log odds* of respondents appearing in the *moderate scientific knowledge* group compared to the *low scientific knowledge* group is given by the equation:

$$
\boldsymbol{LOG}\left(\frac{\boldsymbol{MOD}}{\boldsymbol{low}}\right) = \mathbf{0.862} + (\mathbf{-0.348} \times \boldsymbol{PopW}) + (\mathbf{-0.347} \times \boldsymbol{PopB}) + (\mathbf{-1.214} \times \boldsymbol{PopI}) + (\mathbf{-0.542} \times \boldsymbol{EduLow}) + (\mathbf{0.014} \times \boldsymbol{EduMod}) + (\mathbf{-0.854} \times \boldsymbol{HHILow}) + (\mathbf{-0.409} \times \boldsymbol{HHIMod})
$$

While the log odds of respondents appearing in the *high scientific knowledge* group compared to the *low scientific knowledge* group is represented by the equation:

$$
\boldsymbol{LOG}\left(\frac{\boldsymbol{HIGH}}{\boldsymbol{low}}\right) = \mathbf{1.113} + (\mathbf{0.085} \times \boldsymbol{PopW}) + (\mathbf{-0.206} \times \boldsymbol{PopB}) + (\mathbf{-0.404} \times \boldsymbol{PopI}) + (\mathbf{-0.124} \times \boldsymbol{EduLow}) + (\mathbf{-0.016} \times \boldsymbol{EduMod}) + (\mathbf{-1.166} \times \boldsymbol{HHILow}) + (\mathbf{-0.481} \times \boldsymbol{HHIMod})
$$

Where: the applicable indication of each of the below variable definitions can be substituted

PopW – Race: White	PopB - Race: Black	PopI - Race: Indian	
EduLow – Low Education	EduMod- Moderate Education	HHILow – Low Income	HHIMod- Moderate Income

Predictors of outcomes on the *Attitudes to Science Index* (ASi)

The analysis of outcomes on the *Attitudes to Science Index* within they multinomial logistic regression procedures included valid response from 2 140 respondents as a result of case-wise deletion described earlier. Among the seven predictor variables included within the analysis, 6 were removed as a result of their chi-square result. The variables excluded from the final model include: *educational attainment level; employment status; rural-urban location; household income; age* and *gender*. One variable therefore constituted the final model of predictors on the *attitudes to science index* (L: 18.927; $d.f.$ = 6; $p < 0.01$). Test statistics are presented in table 11.27 discussing the results of the *model fitting information, goodness-of-fit* and *likelihood ratio test*.

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1925.212			
Final	1906.285	18.927	6	0.004

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	1093.869	1068	0.284

Likelihood Ratio Tests				
Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1906.285	0.000	0	
DEMOG_RACE	1925.212	18.927	6	0.004

Table 11.27: Model fitting information, goodness-of-fit and likelihood ratio test

Despite the fact that only a single variable was retained explaining the data within this model, the chi-square and *p-value* indicate a significant association and therefore represents an improvement over the intercept-only model. The Pearson's chi-square within the *goodness-of-fit* table demonstrates that the predicted values fits the observed data points very well as a result of the *p-value* being greater than 0.05. The outcome of the *likelihood ratio test* indicates that race of respondent is significantly associated with outcomes on the *attitudes to science index*, more so than the 6 variables removed during the step-wise elimination process.

Table 11.28 presents the significant categories within the *race* variable constituting this model.

	Predictor	*B*	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
Ambivalent compared to Negative attitude	DEMOG_RACE - White (1)	-0.328	0.292	0.720	0.406	1.278
	DEMOG_RACE - Black (2)	0.079	0.236	1.082	0.682	1.717
	DEMOG_RACE - Indian / Asian (3)	-0.061	0.394	0.941	0.435	2.036
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference

	Predictor	*B*	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
Positive compared to Negative attitude	DEMOG_RACE - White (1)	-0.487	0.260	**0.614**	0.369	1.023
	DEMOG_RACE - Black (2)	-0.491	0.212	**0.612**	0.404	0.927
	DEMOG_RACE - Indian / Asian (3)	-0.335	0.359	0.716	0.354	1.445
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference

Table 11.28: *Attitudes to science index:* Parameter estimates (Reference category: Negative attitude)

As seen within the chi-square analysis in the earlier chapters, there is a strong relationship between *race* and *attitudes to science*. In table 11.28 the black race group is shown to demonstrate a significant association to outcomes on the *attitudes to science index*. Within this result, black respondents are only 61.2% as likely as coloured respondents to display a *positive attitude* to science, over a *negative attitude* to science (B = -0.491; Wald= 5.382; $p < 0.05$). As a result of the high proportion of positive attitudinal response received from within the coloured sub-sample, white respondents were similarly found to only be 61.4% as likely as the former to demonstrate positive attitudes compared to negative attitudes (B = -0.487; Wald= 3.501; $p < 0.01$). When reference categories are switched from the coloured sub-sample to the white sub-sample, a similar picture emerges. Black respondents are 66.6% as likely as white respondents to display a *negative attitude* compared to an *ambivalent attitude* to science (B = -0.407; Wald= 4.211; $p < 0.05$), while the same sub-sample remain 66.3% as likely as white respondents to demonstrate a *positive attitude* over an *ambivalent attitude* to science (B = -0.410; Wald= 5.994; $p < 0.05$ - not shown in table).

These results are reflective of the significant association between race and attitudes to science. Black South Africans demonstrate significant propensity toward ambivalent attitudes to science. There is no doubt that the significance of *race* must include the effect of interactions with related socioeconomic variables that are influencing the recorded attitudinal responses within this research. It may transpire within future research that the influence of increased educational outcomes on attitudes to science may develop a more *critical* attitudinal response.

The model developed from these results for a function of the *log odds* of respondents appearing in the *ambivalent attitudes* group compared to the *negative attitudinal* group is represented by the following equation:

$$\boldsymbol{LOG}\left(\frac{\boldsymbol{AMBIV}}{\boldsymbol{neg}}\right) = \mathbf{0.466} + (-\mathbf{0.328} \times \boldsymbol{PopW}) + (\mathbf{0.079} \times \boldsymbol{PopB}) + (-\mathbf{0.061} \times \boldsymbol{PopI})$$

Conversely, the log odds of respondents appearing in the *positive attitudinal* group, compared to those appearing in the *negative attitude* group are defined in the following equation:

$$\boldsymbol{LOG}\left(\frac{\boldsymbol{POS}}{\boldsymbol{neg}}\right) = \mathbf{1.226} + (-\mathbf{0.487} \times \boldsymbol{PopW}) + (-\mathbf{0.491} \times \boldsymbol{PopB}) + (-\mathbf{0.335} \times \boldsymbol{PopI})$$

Where: the applicable indication of each of the below variable definitions can be substituted

PopW – Race: White	PopB - Race: Black	PopI - Race: Indian

<u>Predictors of outcomes on the *Interest in Science Index* (ISi)</u>

The analysis of predictors of outcomes on the *Interest in Science Index* was based on a total valid sample of 1 748 respondents. Adopting the earlier discussed multinomial logistic regression procedure in SPSS with *step-wise* (backward) *elimination*, 4 variables of the 7 initially included were removed as a result of the outcome of the likelihood ratio test. The final model included three (3) variables that were found to be significantly associated with the outcome variable (L: 92.107; $d.f.$ = 12; p < 0.001). The variables excluded from this final model include: *gender*; *employment status*; *household income* and *age*. The result for the *model fitting information, goodness-of-fit* and *likelihood ratio test* all reveal good overall model statistics and will be discussed in conjunction with table 11.29.

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	1768.065			
Final	1675.958	92.107	12	0.000

Goodness-of-Fit			
	Chi-Square	**df**	**Sig.**
Pearson	965.698	932	0.216

Likelihood Ratio Tests				
Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1675.958	0.000	0	
DEMOG_RURAL_URBAN	1687.602	11.643	2	0.003
DEMOG_EDUCATION	1710.237	34.279	4	0.000
DEMOG_RACE	1702.917	26.959	6	0.000

Table 11.29: Model fitting information, goodness-of-fit and likelihood ratio test

A significant chi-square and p-value are observed within the *model fitting information* table, indicating that the retained variables significantly improve the overall model, compared to the intercept-only model. The Pearson's correlation coefficient is shown not to be statistically significant at the 0.05 level and as a result indicates that the final model fits the data well due to the predicted values not being significantly different from the observed values. The *likelihood ratio test* contains the variables retained within the model and their statistically significant p-values indicate the importance of their retention (see table 11.29).

Significant contributions to the overall significance of the model are observed in both sections of table 11.30.

					95% CI	
	Predictor	*B*	SE (B)	Odds Ratio	Lower bound	Upper Bound
Moderate compared to Low INTEREST	DEMOG_RURAL_URBAN - URBAN	-0.051	0.128	0.950	0.740	1.221
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.396	0.200	**0.673**	0.455	0.995
	DEMOG_EDUCATION - Moderate (2)	-0.079	0.189	0.924	0.638	1.338
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RACE - White (1)	0.355	0.276	1.426	0.831	2.447
	DEMOG_RACE - Black (2)	0.341	0.194	1.406	0.961	2.058
	DEMOG_RACE - Indian / Asian (3)	0.991	0.429	**2.695**	1.163	6.243
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference

					95% CI	
	Predictor	*B*	SE (B)	Odds Ratio	Lower bound	Upper Bound
High compared to Low INTEREST	DEMOG_RURAL_URBAN - URBAN	0.386	0.140	**1.471**	1.118	1.934
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-1.056	0.197	**0.348**	0.236	0.512
	DEMOG_EDUCATION - Moderate (2)	-0.521	0.181	**0.594**	0.417	0.846
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RACE - White (1)	1.189	0.315	**3.282**	1.769	6.089
	DEMOG_RACE - Black (2)	1.145	0.256	**3.143**	1.903	5.193
	DEMOG_RACE - Indian / Asian (3)	1.320	0.482	**3.743**	1.455	9.630
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference

Table 11.30: Interest in science index*:* Parameter estimates (Reference category: Low interest)

As far as educational attainment is concerned, respondents with low education were 67.3% as likely as those with a post-matric education to appear in the *moderate interest* outcome compared to the *low interest* outcome category (B = -3.96; Wald= 3.939; p < 0.05). Likewise, respondents with low educational attainment were only 34.8% as likely as respondents with high educational attainment to appear in the high interest grouping compared to the low interest group (B = -1.056; Wald= 28.730; p < 0.001). Demonstrating an improvement on the former, respondents with a moderate level of education were found to be 59.4% as likely as respondents with high educational attainment to be classified in the high interest group compared to the low interest group (B = -0.521; Wald= 8.314; p < 0.01). Changing the reference group from the *high educational attainment* group to the *low educational attainment* group, a significant association is observed wherein individuals with high education and moderate education were, respectively 1.5 and 1.4 times more likely to be within the *moderate interest* group, than in the *low interest* group compared to respondents with low educational attainment (pre-matric). A similar pattern was observed within the output for the high interest group, respondents with high educational attainment were 2.8 times more likely to appear in the high interest group compared to those with a pre-matric, while those with a completed matric were 1.7 times more likely than those with pre-matric education to appear in this interest group classification compared to the low interest group.

Respondents' geographic location was found to be another significant predictor within the multinomial logistic regression model. Urban respondents were 1.5 times more likely to be classified within the high scientific interest category than the low scientific interest outcome, compared to rural respondents (B= 0.386; Wald= 7.625; p < 0.01).

Race was again found to be statistically significant within this model. Indian / Asian respondents were 2.7 times more likely than coloured respondents to appear in the *moderate interest* group than the *low interest* group (B = 0.991; Wald= 5.348; p < 0.05). Indian / Asian respondents were further 3.7 times more likely to appear in the *high interest* group compared to coloured respondents, than in the *low scientific interest* group (B= 1.320; Wald= 7.492; p < 0.01). White and black respondents were similarly 3.2 and 3.1 times (respectively) more likely than coloured respondents to appear in the high scientific interest group than in the low interest group (White: B= 1.189; Wald= 14.210; p < 0.001; Black: B= 1.145; Wald= 19.994; p < 0.001).

The particularly low interest demonstrated by respondents within the coloured sub-sample ties in with the earlier analysis within this chapter. Coloured respondents are less likely to appear in the high interest response category and more likely to appear in the low scientific interest category. The influence of education is as expected and appears to be an important predictor of performance within this index. However, race continues to demonstrate a large effect on overall performance on this indicator.

Accordingly, the multinomial logistic regression model representing the *log odds* of respondents appearing in the *moderate scientific interest* group compared to the *low scientific interest* group is given by the equation:

$$\mathbf{LOG}\left(\frac{\mathbf{MOD}}{\mathbf{low}}\right) = -\mathbf{0.049} + (-\mathbf{0.051} \times \mathbf{LOC} - \mathbf{URB}) + (-\mathbf{0.396} \times \mathbf{EduLow}) + (-\mathbf{0.079} \times \mathbf{EduMod}) + (\mathbf{0.355} \times \mathbf{PopW}) + (\mathbf{0.341} \times \mathbf{PopB}) + (\mathbf{0.991} \times \mathbf{PopI})$$

While the log odds of respondents appearing in the *high scientific interest* group compared to the *low interest* group is represented by the equation:

$$\mathbf{LOG}\left(\frac{\mathbf{HIGH}}{\mathbf{low}}\right) = -\mathbf{0.768} + (\mathbf{0.386} \times \mathbf{LOC} - \mathbf{URB}) + (-\mathbf{1.056} \times \mathbf{EduLow}) + (-\mathbf{0.521} \times \mathbf{EduMod}) + (\mathbf{1.189} \times \mathbf{PopW}) + (\mathbf{1.145} \times \mathbf{PopB}) + (\mathbf{1.320} \times \mathbf{PopI})$$

Where: the applicable indication of each of the below variable definitions can be substituted

PopW – Race: White	PopB - Race: Black	PopI - Race: Indian	LOC-URB – Urban Location
EduLow – Low Education	EduMod- Moderate Education	HHILow – Low Income	HHIMod- Moderate Income

Predictors of outcomes on the *Informedness in Science Index* (InSi)

The multinomial logistic regression model of predictors of outcomes on the *Informedness in Science Index* is based on 2 173 valid observations as a result of *case-wise* deletion procedures (L: 248.106; $d.f.$ = 30; p < 0.001). Only one variable was removed during the analytic process, as it was found not be significantly associated (*gender*). Table 11.31 presents the m*odel fitting information, goodness-of-fit* and *likelihood ratio test,* where all test statistics were found to be within the acceptable level and the model was demonstrated to be a good fit within the observed data.

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	2157.452			
Final	1909.346	248.106	30	0.000

Goodness-of-Fit			
	Chi-Square	**df**	**Sig.**
Pearson	1096.869	1054	0.175

Likelihood Ratio Tests				
	Model Fitting Criteria	**Likelihood Ratio Tests**		
Effect	**-2 Log Likelihood of**	**Chi-**	**df**	**Sig.**

	Reduced Model	Square		
Intercept	1909.346	0.000	0	
DEMOG_POP_GROUP	1952.898	43.552	6	0.000
DEMOG_RURAL_URBAN	1935.669	26.323	2	0.000
DEMOG_AGE	1927.588	18.242	10	0.051
DEMOG_EDUCATION	1958.322	48.976	4	0.000
DEMOG_EMPLOYMENT	1920.439	11.093	4	0.026
DEMOG_HH_INCOME	1918.291	8.945	4	0.063

Table 11.31: Model fitting information, goodness-of-fit and likelihood ratio test

The variables retained within the model include race*; geographic location (rural - urban); age; educational attainment; employment status* and *household income*. All of these variables, except age, demonstrated a significant p-value within the likelihood test table (table 11.31), however despite the value associated with the age variable – it was retained by SPSS within the final model.

Race of respondent was a significant factor within the *informedness in science inde*x. Indian / Asian respondents were only 27.1% as likely to be classified into the moderate outcome compared to coloured respondents, than into the low informedness group (B= -1.305; Wald= 15.597; p < 0.001). Similarly, white respondents were about twice as likely as coloured respondents to appear in the high informedness category, than in the low informedness category (B = 0.728; Wald= 6.133; p < 0.05). Black respondents were found to be 1.7 times more likely than coloured respondents to appear in the high informedness group than in the low informedness group, while Indian / Asian respondents were 41.1% as likely as coloured respondents to appear in the former group than the latter (Black: B= 0.474; Wald= 4.687; p < 0.05; Indian / Asian: B= -0.890; Wald= 5.849; p < 0.05).

With reference to geography, urban respondents are 1.6 times more likely than rural respondents to be classified in the moderate informedness category than the low informedness category (B= 0.477; Wald= 16.497; p < 0.001). Similarly, urban respondents were found to be 1.8 times more likely to appear in the high informedness group than the low informedness group compared to rural respondents (B= 0.592; Wald= 22.239; p < 0.001).

Based on the earlier analysis in Chapter Eight, level of educational attainment was expected to be significantly associated with the informedness in science index. Respondents within pre-matric education are only 48.4% as likely as those with post-matric education to appear in the moderate informedness group than in the low informedness group (B= -0.726; Wald= 10.511; p < 0.01), while respondents with a completed matric were 63.7% as likely as those with a post-matric education to be in the moderate category, compared to the low category (B = -0.450; Wald= 4.724; p < 0.05). Accordingly, those with pre-matric education and a completed matric were less likely to appear in the high informedness category, compared to those with a post-matric education (Pre-matric: B= -1.444; Wald= 42.632; p < 0.001; Matric completed: B= -0.818; Wald= 16.934; p < 0.001).

					95% CI	
	Predictor	***B***	**SE (B)**	**Odds Ratio**	**Lower bound**	**Upper Bound**
Moderate compared to Low INFORMEDNESS	DEMOG_RACE - White (1)	-0.342	0.280	0.710	0.410	1.230
	DEMOG_RACE - Black (2)	-0.269	0.183	0.764	0.534	1.094
	DEMOG_RACE - Indian / Asian (3)	-1.305	0.330	**0.271**	0.142	0.518
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RURAL_URBAN - URBAN	0.477	0.117	**1.611**	1.280	2.028
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_AGE - <20 years	0.453	0.347	1.572	0.797	3.101
	DEMOG_AGE - 20-29 years	0.151	0.239	1.163	0.728	1.860
	DEMOG_AGE - 30-39 years	-0.004	0.243	0.996	0.619	1.603
	DEMOG_AGE - 40-49 years	0.375	0.252	1.455	0.888	2.384
	DEMOG_AGE - 50-59 years	0.059	0.267	1.061	0.629	1.791
	DEMOG_AGE 60+ years	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.726	0.224	**0.484**	0.312	0.750
	DEMOG_EDUCATION - Moderate (2)	-0.450	0.207	**0.637**	0.425	0.957
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_EMPLOYMENT - Employed	0.494	0.184	**1.640**	1.143	2.352
	DEMOG_EMPLOYMENT - Unemployed	0.456	0.184	**1.577**	1.099	2.264
	DEMOG_EMPLOYMENT - Not-Working	Reference	Reference	Reference	Reference	Reference
	DEMOG_HH_INCOME - Low (1)	-0.560	0.326	0.571	0.302	1.082
	DEMOG_HH_INCOME - Moderate (2)	-0.428	0.318	0.652	0.349	1.216
	DEMOG_HH_INCOME - High (3)	Reference	Reference	Reference	Reference	Reference

					95% CI	
	Predictor	***B***	**SE (B)**	**Odds Ratio**	**Lower bound**	**Upper Bound**
High compared to Low INFORMEDNESS	DEMOG_RACE - White (1)	0.728	0.294	**2.070**	1.164	3.683
	DEMOG_RACE - Black (2)	0.474	0.219	**1.607**	1.046	2.470
	DEMOG_RACE - Indian / Asian (3)	-0.890	0.368	**0.411**	0.200	0.845
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RURAL_URBAN - URBAN	0.592	0.125	**1.807**	1.414	2.309
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_AGE - <20 years	1.131	0.354	**3.099**	1.548	6.204
	DEMOG_AGE - 20-29 years	0.350	0.262	1.420	0.849	2.374
	DEMOG_AGE - 30-39 years	0.161	0.266	1.175	0.698	1.977
	DEMOG_AGE - 40-49 years	0.311	0.278	1.364	0.791	2.353
	DEMOG_AGE - 50-59 years	0.237	0.291	1.268	0.716	2.245
	DEMOG_AGE 60+ years	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-1.444	0.221	**0.236**	0.153	0.364
	DEMOG_EDUCATION - Moderate (2)	-0.818	0.199	**0.441**	0.299	0.652
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
	DEMOG_EMPLOYMENT - Employed	0.550	0.193	**1.734**	1.188	2.530
	DEMOG_EMPLOYMENT - Unemployed	0.529	0.196	**1.697**	1.156	2.492
	DEMOG_EMPLOYMENT - Not-Working	Reference	Reference	Reference	Reference	Reference
	DEMOG_HH_INCOME - Low (1)	-0.839	0.318	**0.432**	0.232	0.805
	DEMOG_HH_INCOME - Moderate (2)	-0.525	0.308	**0.592**	0.324	1.081
	DEMOG_HH_INCOME - High (3)	Reference	Reference	Reference	Reference	Reference

Table 11.32: *Informedness in science index:* Parameter estimates (Reference category: Low informedness)

Respondents who are employed are 1.6 times more likely to appear in the moderate group than the low group and 1.7 more likely to appear in the high informedness group than the low informedness group than respondents not working (Moderate: B = 0.494; Wald= 7.208; $p < 0.01$; High: B = 0.550; Wald= 8.155; $p < 0.01$). Interestingly, unemployed respondents were 1.5 times more likely to appear in the moderate informedness group than the low informedness group and 1.7 times more likely to appear in the high informdness group than the low informedness group than those reporting they are not working (Moderate: B = 0.456; Wald= 6.103; p < 0.01; High: B = 0.529; Wald= 7.300; p < 0.01).

The role of income revealed that individuals within lower income households were 43.2% as likely as those with high household income to be in the high informedness group compared to the low informedness group (B= -0.839; Wald= 6.976, p < 0.01). Respondents reporting moderate household income were 59.2% as likely as those within the high household income category to be within the high group than in the low informedness group (B= -0.525; Wald= 2.910; p < 0.05).

The multinomial logistic regression model representing the *log odds* of respondents appearing in the *moderate informedness* group compared to the *low informedness* group is provided within the equation:

$$\begin{aligned}\boldsymbol{LOG}\left(\frac{\boldsymbol{MOD}}{\boldsymbol{low}}\right) = &\ \mathbf{0.604} + (-\mathbf{0.342} \times \boldsymbol{PopW}) + (-\mathbf{0.269} \times \boldsymbol{PopB}) + (-\mathbf{1.305} \times \boldsymbol{PopI}) \\ &+ (\mathbf{0.477} \times \boldsymbol{LocUrb}) + (-\mathbf{0.453} \times \boldsymbol{Age1}) + (\mathbf{0.151} \times \boldsymbol{Age2}) \\ &+ (-\mathbf{0.004} \times \boldsymbol{Age3}) + (\mathbf{0.375} \times \mathbf{Age4}) + (\mathbf{0.059} \times \mathbf{Age5}) \\ &+ (-\mathbf{0.726} \times \mathbf{EduLOW}) + (-\mathbf{0.450} \times \mathbf{EduMOD}) + (\mathbf{0.494} \times \mathbf{Empl1}) \\ &+ (\mathbf{0.456} \times \mathbf{Empl2}) + (-\mathbf{0.560} \times \boldsymbol{HHILow}) + (-\mathbf{0.428} \times \boldsymbol{HHIMod})\end{aligned}$$

While the log odds of respondents appearing in the *high informedness* category compared to the *low informedness* category is represented by the equation:

$$\begin{aligned}\boldsymbol{LOG}\left(\frac{\boldsymbol{HIGH}}{\boldsymbol{low}}\right) = &\ \mathbf{0.184} + (\mathbf{0.728} \times \boldsymbol{PopW}) + (\mathbf{0.474} \times \boldsymbol{PopB}) + (-\mathbf{0.890} \times \boldsymbol{PopI}) \\ &+ (\mathbf{0.592} \times \boldsymbol{LocUrb}) + (\mathbf{1.131} \times \boldsymbol{Age1}) + (\mathbf{0.350} \times \boldsymbol{Age2}) \\ &+ (\mathbf{0.161} \times \boldsymbol{Age3}) + (\mathbf{0.311} \times \mathbf{Age4}) + (\mathbf{0.237} \times \mathbf{Age5}) \\ &+ (-\mathbf{1.444} \times \mathbf{EduLOW}) + (-\mathbf{0.818} \times \mathbf{EduMOD}) + (\mathbf{0.550} \times \mathbf{Empl1}) \\ &+ (\mathbf{0.529} \times \mathbf{Empl2}) + (-\mathbf{0.839} \times \boldsymbol{HHILow}) + (-\mathbf{0.525} \times \boldsymbol{HHIMod})\end{aligned}$$

Where: the applicable indication of each of the below variable definitions can be substituted

PopW – Race: White	PopB - Race: Black	PopI - Race: Indian	EduLow – Low Education
EduMod- Moderate Education	HHILow – Low Income	HHIMod- Moderate Income	Age1 - <20 years
Age2 – 20-29 years	Age3 – 30-39 years	Age4 – 40-49 years	Age5 – 50-59 years
Empl1 - Employed	Empl2 - Unemployed	LocUrb - Urban	

Predictors of outcomes on the *Information Immersion Science Index* (InfoSI)

An assessment of predictors for the *scientific information immersion index* adopting a multinomial logistic regression model yielded a significant outcome (L: 237.003; $d.f.$ = 22; $p < 0.001$). The analysis involved 2 101 valid cases, equalling 60.2% of the total sample. Within the model procedure, three variables were not found to significantly influence the outcome and were excluded from further analysis. These include: *employment status; household income* and *gender*.

Model Fitting Information				
Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	2090.208			
Final	1853.206	237.003	22	0.000

Goodness-of-Fit			
	Chi-Square	**df**	**Sig.**
Pearson	1058.372	1044	0.372

Likelihood Ratio Tests				
Effect	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	-2 Log Likelihood of Reduced Model	**Chi-Square**	**df**	**Sig.**
Intercept	1853.206	0.000	0	
DEMOG_RACE	1873.267	20.061	6	0.003
DEMOG_RURAL_URBAN	1863.895	10.689	2	0.005
DEMOG_AGE	1880.020	26.814	10	0.003
DEMOG_EDUCATION	1958.253	105.047	4	0.000

Table 11.33: Model fitting information, goodness-of-fit and likelihood ratio test

The model fitting information and related test statistic are presented in the compound table 11.33. The model fitting information demonstrates a significant chi-square and p-value, indicating that the included variables had a significant improvement on the intercept-only model. An assessment of the *goodness-of-fit* information reveals how well the model fits the observed data within the study. The *p-value* equals a value greater than 0.05, indicating that the model fits the data well. The variables retained within the model are presented within the *likelihood ratio test* and include: *race group; educational attainment*; *rural - urban location* and *age* as a result of their statistically significant *p-value* (see table 11.33).

The influence of age group classification appears to be highly significant within this model. Respondents below the age of 60 year are significantly less likely to be assigned to the low information immersion group than respondents older than 60 years. People aged between 50 and 59 are 1.9 times more likely to be assigned to the moderate information immersion category than the low information immersion category, compared to those 60 years and older (B= -0.647; Wald= 6.711; *p* < 0.01). Similarly, respondents aged below 60 years were in most cases twice as likely as those aged 60 years and older to appear in the high information immersion group than in the low group. Among respondents aged less than 20 years this odds ratio was found to be 2.7 times more than for those aged 60+ years (B= 1.005; Wald= 7.564; *p* < 0.01).

	Predictor	*B*	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
Moderate compared to Low information immersion	DEMOG_RACE - White (1)	-0.151	0.294	0.860	0.483	1.531
	DEMOG_RACE - Black (2)	-0.386	0.206	0.680	0.454	1.017
	DEMOG_RACE - Indian / Asian (3)	-0.353	0.364	0.702	0.344	1.434
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RURAL_URBAN - URBAN	0.209	0.119	1.232	0.975	1.557
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_AGE - <20 years	0.257	0.343	1.293	0.660	2.535
	DEMOG_AGE - 20-29 years	0.115	0.218	1.122	0.732	1.719
	DEMOG_AGE - 30-39 years	0.266	0.214	1.304	0.857	1.985
	DEMOG_AGE - 40-49 years	0.232	0.227	1.262	0.808	1.970
	DEMOG_AGE - 50-59 years	0.647	0.250	**1.910**	1.171	3.116
	DEMOG_AGE 60+ years	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.629	0.208	**0.533**	0.354	0.802
	DEMOG_EDUCATION - Moderate (2)	-0.565	0.202	**0.568**	0.383	0.845
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference

	Predictor	*B*	SE (B)	Odds Ratio	95% CI Lower bound	95% CI Upper Bound
High compared to Low information immersion	DEMOG_RACE - White (1)	0.177	0.282	1.193	0.686	2.074
	DEMOG_RACE - Black (2)	-0.544	0.207	**0.580**	0.387	0.871
	DEMOG_RACE - Indian / Asian (3)	-0.180	0.352	0.835	0.419	1.665
	DEMOG_RACE - Coloured (4)	Reference	Reference	Reference	Reference	Reference
	DEMOG_RURAL_URBAN - URBAN	0.405	0.124	**1.499**	1.175	1.912
	DEMOG_RURAL_URBAN - RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_AGE - <20 years	1.005	0.365	**2.731**	1.335	5.588
	DEMOG_AGE - 20-29 years	0.876	0.254	**2.401**	1.460	3.948
	DEMOG_AGE - 30-39 years	0.716	0.252	**2.046**	1.248	3.355
	DEMOG_AGE - 40-49 years	0.898	0.262	**2.456**	1.470	4.102
	DEMOG_AGE - 50-59 years	0.801	0.293	**2.228**	1.256	3.955
	DEMOG_AGE 60+ years	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-1.779	0.201	**0.169**	0.114	0.250
	DEMOG_EDUCATION - Moderate (2)	-0.910	0.185	**0.403**	0.280	0.578
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference

Table 11.34: *Information Immersion Science Index* Parameter estimates (Reference category: Low information immersion)

Within race, only a single predictor made a unique statistically significant contribution. Black respondents were 58.0% as likely as coloured respondents to appear in the high information immersion group than in the low group (B= -0.544; Wald= 6.894; *p* < 0.01).

Educational attainment groups reveal that respondents with pre-matric education are 53.3% as likely as those with post-matric education to appear in the moderate information immersion group, as they are to appear in the low information immersion group (B = -0.629; Wald= 9.100; $p < 0.01$). Similarly, these respondents within the low educational attainment group are only 16.9% as likely as post-matriculants to appear in the high information immersion group than they are to appear in the low information immersion group (B = -1.799; Wald= 78.554; $p < 0.001$). Respondents with a moderate educational attainment (completed matric) are 56.8% as likely as those with post-matric education to appear in the moderate group compared to the high information immersion group, while these same respondents in the moderate education category are only 40.3% as likely to appear in the high information immersion group as they are to appear in the low group compared to respondents with post-matric education (Moderate: B = -0.565; Wald= 7.816; $p < 0.01$; High: B = -0.910; Wald= 24.282; $p < 0.001$).

Further to the above, the predicted parameter estimates indicates that urban respondents are 1.5 times more likely to appear in the high information immersion response category than in the low category, compared to rural respondents (B = 0.405; Wald= 10.610; $p < 0.01$).

These outputs from the multinomial logistic regression indicate that *age* remains a key factor within information immersion regarding science. Access to and willingness to engage a broader frequency and selection of information mediums demonstrates a significant association to age group within this indicator. The other three variables, similarly produced significant results, however the finding within the age variable remains a key point toward additional research.

The *log odds* of respondents appearing in the *moderate* information immersion index group compared to the *low* information immersion index group is given by the equation:

$$\begin{aligned}\boldsymbol{LOG\left(\frac{MOD}{low}\right)} &= \mathbf{0.487} + (\mathbf{-0.151} \times \boldsymbol{PopW}) + (\mathbf{-0.386} \times \boldsymbol{PopB}) + (\mathbf{-0.353} \times \boldsymbol{PopI}) \\ &+ (\mathbf{0.209} \times \boldsymbol{LocUrb}) + (\mathbf{0.257} \times \boldsymbol{Age1}) + (\mathbf{0.115} \times \boldsymbol{Age2}) \\ &+ (\mathbf{0.266} \times \boldsymbol{Age3}) + (\mathbf{0.232} \times \mathbf{Age4}) + (\mathbf{0.647} \times \mathbf{Age5}) \\ &+ (\mathbf{-0.629} \times \mathbf{EduLOW}) + (\mathbf{-0.565} \times \mathbf{EduMOD})\end{aligned}$$

Log odds of respondents appearing in the *high* knowledge compared to *low* knowledge group:

$$\begin{aligned}\boldsymbol{LOG\left(\frac{HIGH}{low}\right)} &= \mathbf{0.536} + (\mathbf{0.177} \times \boldsymbol{PopW}) + (\mathbf{-0.544} \times \boldsymbol{PopB}) + (\mathbf{-0.180} \times \boldsymbol{PopI}) \\ &+ (\mathbf{0.405} \times \boldsymbol{LocUrb}) + (\mathbf{1.005} \times \boldsymbol{Age1}) + (\mathbf{0.876} \times \boldsymbol{Age2}) \\ &+ (\mathbf{0.716} \times \boldsymbol{Age3}) + (\mathbf{0.898} \times \mathbf{Age4}) + (\mathbf{0.801} \times \mathbf{Age5}) \\ &+ (\mathbf{-1.779} \times \mathbf{EduLOW}) + (\mathbf{-0.910} \times \mathbf{EduMOD})\end{aligned}$$

Where: the applicable indication of each of the below variable definitions can be substituted

PopW – Race: White	PopB - Race: Black	PopI - Race: Indian	LocUrb- Urban
EduLow – Low Education	EduMod- Moderate Education	Age1 - <20 years	Age5 – 50-59 years
Age2 – 20-29 years	Age3 – 30-39 years	Age4 – 40-49 years	Age5 – 50-59 years

Predictors of outcomes on the *Science Engagement Index* (SEI)

An investigation into the predictors of outcomes on the *science engagement index* was completed using the procedures adopted previously. As reported in the previous chapters, the majority of South Africans (84.9%) had not visited a science engagement activity within the preceding 12 month period and as a result, the multinomial logistic regression analysis was performed using a base starting sample of 950 respondents. Due to the manner in which SPSS initiates the NOMREG (multinomial logistic regression) procedure, cases with cells containing zero (0) frequencies were eliminated and thus the final analysis included 606 respondents (63.7%).

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	861.923			
Final	821.920	40.003	6	0.000

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	585.576	568	0.296

Likelihood Ratio Tests				
	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	821.920	0.000	0	
DEMOG_RURAL_URBAN	837.710	15.789	2	0.000
DEMOG_EDUCATION	840.008	18.088	4	0.001

Table 11.35: Model fitting information, goodness-of-fit and likelihood ratio test

The *step-wise backward elimination* process in the multinomial logistic regression removed the variables relating to: race*; employment status; age; household income* and *gender*. The final model included *geographic location* (rural - urban) as well as *educational attainment* and was found to be significant (L: 40.003; $d.f.$ = 6; $p < 0.001$). The result for the *model fitting information, goodness-of-fit* and *likelihood ratio test* are presented in table 11.35.

Test outputs indicate a significant model fitting chi-square value for the variables included as compared to the intercept-only model. The predicted data values within the model fit the actual observations very well as suggested by the chi-square value and outcome of the test of significance which yielded a *p*-value greater than 0.05. The likelihood ratio tests for variables retained in the model indicate both as highly significant predictors of performance on the science engagement index.

					95% CI	
	Predictor	***B***	**SE (B)**	**Odds Ratio**	**Lower bound**	**Upper Bound**
Moderate compared to Low engagement	DEMOG_RURAL_URBAN – URBAN	0.221	0.235	1.248	0.788	1.977
	DEMOG_RURAL_URBAN – RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-0.011	0.311	0.989	0.538	1.819
	DEMOG_EDUCATION - Moderate (2)	-0.058	0.253	0.944	0.575	1.548
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference
					95% CI	
	Predictor	***B***	**SE (B)**	**Odds Ratio**	**Lower bound**	**Upper Bound**
High compared to Low engagement	DEMOG_RURAL_URBAN – URBAN	1.061	0.286	**2.891**	1.651	5.061
	DEMOG_RURAL_URBAN – RURAL	Reference	Reference	Reference	Reference	Reference
	DEMOG_EDUCATION - Low (1)	-1.211	0.337	**0.298**	0.154	0.577
	DEMOG_EDUCATION - Moderate (2)	-0.663	0.223	**0.516**	0.333	0.799
	DEMOG_EDUCATION - High (3)	Reference	Reference	Reference	Reference	Reference

Table 11.36: *Science Engagement Index* Parameter estimates (Reference category: Low engagement)

Both variables produced statistically significant results, as far as science engagement is concerned, particularly within the high engagement outcome group. Urban respondents were 2.9 times more likely than rural respondents to appear in the high science engagement outcome, than the low outcome group (B = 1.061; Wald= 13.798; $p < 0.001$).

Educational attainment level was again found to correlate significantly to outcomes within the science engagement index. Respondents with low educational attainment (pre-matric) were only 29.8% as likely as those with a post-matric education to be within the high engagement outcome, compared to the low science engagement classification. Respondents with a completed matric were similarly only 51.6% as likely as those within the high educational attainment group to appear in the high science engagement classification compared to the low engagement group. With the reference category set to compare respondents to the low educational attainment group, the converse is revealed. Respondents with post-matric education are 3.4 times more likely than those with a pre-matric education to appear in the high science engagement group compared to the low science engagement group. Respondents with a completed matric were 1.7 times more likely to appear in the high group, than the low engagement group compared to respondents with pre-matric educational attainment.

The result of the multinomial logistic regression is in agreement with the previously reported bivariate analysis and the indicator results presented earlier in this chapter. Predictors of attendance at science engagement activities would in many ways be determined by the overall level of *informedness* and *interest* in science that is highly related to educational attainment.

Correspondingly, beyond the influence of the interactions between geographic location, income, education and employment, the noted role of the rural / urban variable is demonstrative of access and availability of science engagement centres within the rural locations. While the data does not allow us to access *affective* and *motivational* reasons directing attendance at science engagement locations, the simple reality is, *people cannot attend what is not there.* As a result of this analysis it has however been demonstrated that lack of access and availability of science engagement programmes within rural areas negatively influence outcomes on the science engagement index.

The final multinomial logistic regression model representing the *log odds* of respondents appearing in the *moderate* science engagement group compared to the *low* science engagement group is presented within the equation:

$$\boldsymbol{LOG}\left(\frac{\boldsymbol{MOD}}{\boldsymbol{low}}\right) = -\mathbf{0.800} + (\mathbf{0.221} \times \boldsymbol{LocUrb}) + (-\mathbf{0.011} \times \boldsymbol{EduLOW}) + (-\mathbf{0.058} \times \boldsymbol{EduMOD})$$

While the log odds of respondents appearing in the *high* science engagement group compared to the *low* science engagement group is represented by the equation:

$$\boldsymbol{LOG}\left(\frac{\boldsymbol{HIGH}}{\boldsymbol{low}}\right) = -\mathbf{0.870} + (\mathbf{1.061} \times \boldsymbol{LocUrb}) + (-\mathbf{1.211} \times \boldsymbol{EduLOW}) + (-\mathbf{0.663} \times \boldsymbol{EduMOD})$$

Where: the applicable indication of each of the below variable definitions can be substituted

LocUrb - Urban	EduLow – Low Education	EduMod- Moderate Education

Chapter Summary and Conclusions

This chapter presented the procedures employed during the construction and validation of the six indicators for the measurement of the South African public understanding of science (SAPUS). The discussion extends from chapter four and five and introduces the indicators produced.

The results reveal that while a large share of South Africans demonstrate a moderate to high level of scientific knowledge, an equally large proportion of respondents displayed a lower level of scientific knowledge within the index. This may be attributable to levels of education and related socioeconomic factors that influence educational attainment, informedness and access to information sources.

South Africans generally present positive attitudes to science. A marginal share of the sample was found to hold more negative attitudes than positive attitudes; this is not unexpected and in certain respects a healthy sign of a population aware of risks and simultaneously supportive of the scientific enterprise. As noted in Chapter Six, a large proportion of respondents demonstrated a degree of attitudinal ambivalence while remains of concern, due to its influence on the strength and direction of national attitudes to science in the long term.

South Africans appear interested in science, though the level of interest does vary greatly between demographic sub-samples. Among the total sample, 67.3% indicated a moderate to high interest in science while 32.7% indicated a low interest, however an interest none-the-less (n = 2 640). Within Chapter Seven it was revealed that 44.4% of the total sample (3 486) indicated no interest in science, which has been shown to significantly impact overall levels of knowledge, informedness and engagement activities.

Within the *Index of Informedness about Science* South Africans report equal levels of informedness across the three response categories. While 33.7% of respondents report a high level of informedness and 33.4% indicate a moderate informedness, 32.8% still report that they do not feel *very well informed* about science. Informedness appears to lag interest in South Africa where levels of interest in science is somewhat higher than reported levels of informedness, for the same items and scientific areas. This remains an intriguing finding within these results.

Within an assessment of the count of information channels accessed as well as the frequency of encountering scientific information within those channels, the *science information immersion index* demonstrated that two-thirds of South Africans have a higher scientific information immersion than the balance of the sample. It remains critical to frame this outcome with issues related to affordability and access to service infrastructure. An assessment of information access and service infrastructure, particularly within rural South Africa remains an important aspect that would further contribute to the outputs of this index.

A key finding of the study is that despite the recorded levels of *knowledge*, *informedness* and reported *interest* in science, the majority of South Africans do not attend *science engagement* activities. The largest proportion of respondents recorded low science engagement scores, while the overwhelming majority of all respondents reported *no engagement* within the preceding 12 month period. While engagement is highly related to access, affordability and relative proximity to engagement locations, the broadening of the science engagement programme from both public and private sources remains a clear area of significant improvement.

The outcomes of the indicator-set combined with a selection of demographic variable inputs allowed for a general segmentation of respondents within this dataset, in terms of the overall public understanding of science (PUS) behaviour. Four categories of the general public were created within this segmentation, profiling those most likely to appear within each segment. The segmentation model represents a *proposal* toward greater refinement of such segmentation techniques within the PUS research area. It is hoped that such techniques will provide guidance and improvement to implement targeted communications and platforms that speak to the segments of society in most critical need of access and interactions with scientific areas.

The predictors of performance on each indicator were assessed using multinomial logistic regression within IBM-SPSS toward developing an understanding of the main demographic variables that influence outcomes on each index. Table 11.37 presents the results for each indicator. The influence of race remains a major predictor of performance most all of the indicators developed. There can be no doubt that this influence is interacting and may in fact be moderated by selected other demographic variables, such as income, employment and education, which compounds the impact and influence of the race variable within these indicators.

Predictor	***Science Knowledge Index***	***Attitudes to Science Index***	***Interest in Science Index***	***Informedness in Science Index***	***Information Immersion Science Index***	***Science Engagement Index***
Race group	✓	✓	✓	✓	✓	
Educational attainment	✓		✓	✓	✓	✓
Household Income	✓			✓		
Geographic location (rural / urban)			✓	✓	✓	✓
Age group				✓	✓	
Employment status				✓		

Table 11.37: Summary of predictors on each indicator

Educational attainment is a significant predictor in all indices, except the attitudinal index. Respondents demonstrating higher education performed increasingly well within each indicator set, clearly noting the value and importance of this variable in predicting outcomes on each index.

Household income was found to be significant as far as knowledge of science and informedness about science is concerned. The relationships between scientific knowledge, interest, informedness, income, education and employment are noted and across this report has demonstrated significant influence on the outputs presented. This was similarly observed where it was found that employment and level of informedness about science was significantly associated.

Rural - urban geographic location was also found to be a significant predictor for *interest in science*, *informedness about science*, *information immersion* and *science engagement.* The geographic availability of services and infrastructure remains a developmental challenge within contemporary South Africa. While great strides have been made toward closing the developmental divide between rural and urban populations, there remains some distance to go toward achieving parity across geographic location sub-samples. As a result of this, location continues to be a significant predictor on SAPUS indices as they influence numerous measurement areas due to the mentioned factors.

Respondent age classification was also found to be significantly associated with level of scientific informedness and degree of information immersion. This may relate to an increasingly diverse array of information sources among younger age classification, compared to more senior respondents. Similarly this outcome may also point to affordability and ease of access within selected demographic groups that demonstrates the significant influence of age classification on information seeking behaviour and reported level of informedness among South Africans.

During the development of indicators for the measurement of the public understanding of science in South Africa, significant evidence was presented toward the identification of viable demographic predictor variables with respect to performance outcomes on each of the six (6) indicators produced. However, as noted in Chapter Four, the multiple determinants involved in the formation of beliefs, attitudes and values that impact on human behaviour in the social context are often complex (Gorsuch; 1969) and beyond the scope of this research. A logical next phase of such research would be to understand the antecedents of the acquisition of knowledge, the formation of attitude, interest and informedness as well as interaction with information sources and engagement activities and how these influence the public understanding of science. The interactions of the identified demographic predictor variables in the South African context introduces further complexity to a proposed dynamic explanatory model of the domestic public understanding of science. As noted by Rokeach (1968) the formation of attitudes (in particular) are not one dimensional, but as a result of interacting multidimensional determinants. This research has identified the variables and statistical relationships that best serve as predictors in statistical models of the South African public understanding of science. However, a theory explaining the formation of attitudinal and related structures, both *physical* and *affective* is still required to understand the complex interaction between knowledge, attitude, interest, informedness, information seeking and engagement behaviours. While these variables and predictors may serve to inform models that predict outcomes on indices, a theoretical formulation is none-the-less still required to explain these interactions within a multi-layered social context. Much work is however still required to understand these interactions prior to the development of such an explanatory theoretical model of the South African public understanding of science.

A summary of the results of the above discussion as well as the outputs coming out of the multinomial logistic regression is presented in image 11.2 below. Within each of the six SAPUS elements, and the respective survey questionnaire items, the factors that best predict the outcomes for each indicator are highlighted. Important to note remains the interacting system of demographic predictors driving scores on SAPUS indicators.

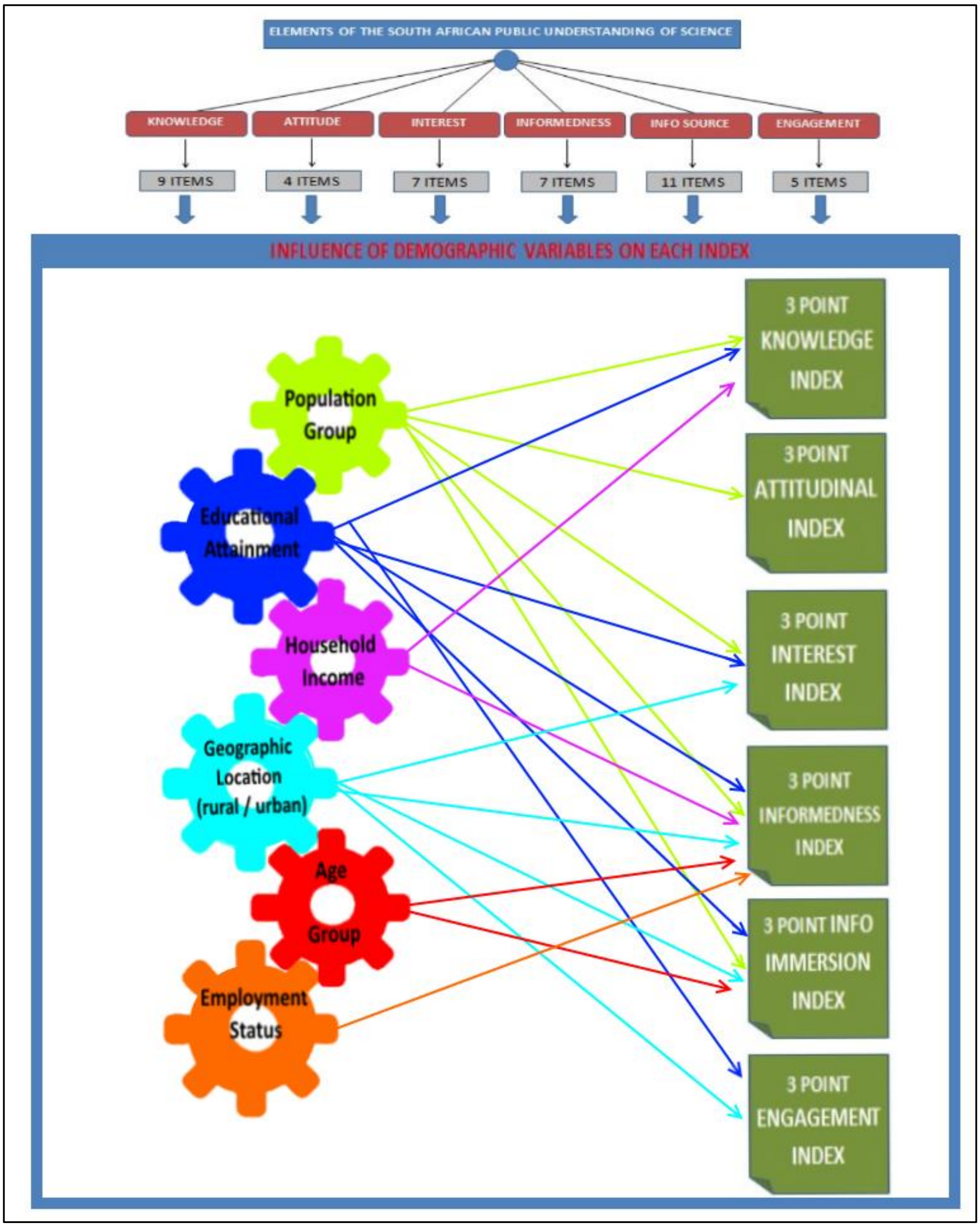


Image 11.2: Predictors of SAPUS indicators within South Africa

The development of explanatory models of predictors of performance for each indicator remains a key development within this study as it lays a foundation for further exploration into the main drivers influencing the South Africa public understanding of science. The results paint a picture of a South African public highly interested, but not as informed as they feel they should be. An assessment of scientific knowledge further confirms a lower level of overall scientific knowledge among the general public. While attitudes to science remain generally positive, the degree of *attitudinal ambivalence* is of concern and further investigation in this area would be required. Overall the level of engagement remains very low among South Africans. Any increases as far as science engagement is concerned would be an organic extension of increased knowledge, interest and reported informedness. A deeper understanding of drivers of attendance at these activities among urban respondents would assist in understanding engagement behaviour antecedents in the future. However, beyond this access and infrastructure remains a key area that may be influencing rural respondents' propensities to attend such science engagement activities.

Chapter Twelve

Summary, Recommendations and Conclusions

"The role of scientific knowledge is to ensure that decisions are made based on fact and knowledge rather than belief, myth and superstition."

Nelson Mandela (13 July 2003)

This chapter presents a summary of the main stages of development, implementation and key findings of the study. The limitations and recommendations for future research are also presented.

12.1 Science in South Africa

The study was conducted in 2015, coinciding with the 21st commemoration of the first democratic elections in South Africa. Within the interceding period, much progress has been made in supporting equality and furthering the cause for basic human rights across South Africa. However, despite the mammoth success achieved as a nation, South Africa still faces an uncertain future as it starts to deal with the multitude of challenges confronting its development, governance and economic growth prospects into the 21st century. Vital to meeting these challenges are solutions seated within the sphere of *science and technology*, that are seen as critical success factors toward accelerating growth, development and social cohesion. Despite this, concern still looms over the suitability of adopting technological innovations within a society that struggles to provide access and infrastructure to satisfy the minimal requirements of a population eager to engage and employ technology toward an enhanced social and economic landscape. While science and technology may well be the best suited mechanism toward bridging the economic divide, the development of a citizenry suitably skilled and equipped to meet the challenges of this new era remains of greater concern on this path toward a truly equal South Africa.

Science and technology (S&T) has had a chequered past and political association within South Africa. While great strides have been made in accelerating development and industry during the 19th and 20th century, much of the progress achieved have only benefitted a minority within the (then) racially segregated population. As a result of race politics, imperial ambition, conflict and the struggle for liberation, science in South Africa has shared an uneasy relationship with the general public. As noted in Chapter One, the history and context of science within the South African setting cannot be separated from the apartheid past, despite (the likelihood of) the best intentions of many practitioners within this early period. In many respects this initial era, irrespective of its uncomfortable past and interconnections with the government of the time, made significant advances toward establishing some of the premier scientific societies and institutions, many of which are still active at the national level within contemporary South Africa. These foundations have laid the groundwork for the national science system and it remains valuable and appropriate to acknowledge these early efforts within a present-day South African national system of innovation.

South Africa is a heterogeneous society, with numerous cultures, languages, religions, traditions and belief systems that give rise to a population unique in its national identity, but diverse in its parts. While much of this diversity is related to the cultural facets alluded to earlier, many social parallels coexist as a result of the legacy impacts of apartheid that influence development, access to basic services and education. Consequently, this leads to the notion of a segmented public which is best considered as multiple publics, than as a homogenous collective. This by no means speaks to issues of national identity, patriotism or social cohesion, though the latter has been challenged in the recent past[144]. What the point does concern however, relates to the notion of a South African society still emerging from the legacy influence of separated development under apartheid, where inequality, income, access to resources, services and education still negatively impact the larger share of the population. This inequality within contemporary South Africa will tremendously influence the country's ability to meet its set developmental goals toward effectively addressing imbalances that permeate all levels of society. The preamble of the South African constitution contains the passage *[to] improve the quality of life of all citizens and free the potential of each person* – however, 20 years following the adoption of this document, as a country we still face challenges toward achieving this goal. To bridge the developmental divide, science and technology has a significant role to play in addressing many of these social and developmental challenges. The ultimate socio-economic objective of such programmes must be to build communities and societies, rich in education and releasing the potential in all citizens to be involved in productive labour and civically active toward building the South Africa envisioned in this foundational document.

Toward this goal, and seating South Africa's developmental and social progress within a science and technology space, the Department of Science and Technology (DST) has formulated numerous policy documents guiding the expanded programme of the scientific enterprise in this country. The 1996 *White Paper on Science and Technology*, the 2008 *Ten-Year Innovation Plan*, the 2012 *National Development Plan* and the future dated *Science Engagement Policy Framework*, have all echoed the vision of a South Africa rising to the challenge of its past and ensuring equality and prosperity for all through the adoption of a knowledge economy framework. These documents further go on to illustrate the potential that science and technology may unleash within the national economy while providing structure toward implementation of programs to accelerate these objectives. While some

[144] Issues of race relations on social media, political contestation and access to education are key events in 2015

of these strategic directives have been operationalised, many well-intended programs remain dormant and must be actioned toward advancing the needs of the people of this country.

Within the current knowledge economy context and changing modes of economic production, there remains a looming crisis of a lack of an adequately skilled science and technology workforce. Moreover the importance of a suitably skilled citizenry, able to meaningfully engage within this changing domestic and increasingly globalised productive landscape remains key toward driving economic and social progress. A citizenry skilled in areas of science and technology is better positioned to make more informed decisions, politically, economically and in every aspect of their lives (Laugksch, 1996). Within this context an exploration of the *public relationship with science* remains an important contribution toward best facilitating the ambitions of the evolving policy and social landscape within contemporary South Africa.

There is a greater need to more fully understand the many segments of the South African public. This remains a national imperative in order to best respond to the many issues impacted by the lack of a general public understanding of science. By understanding the social envelope of the many segments of the South African public, this study has aimed to develop a comprehensive assessment of the numerous interrelated factors that influence the general public understanding and engagement with science. We believe that the finding will allow for the development of strategies that address segments of the populations neglected within this space. A comprehensive assessment of the South African public understanding of science would facilitate targeted communications and educational advancement that would best respond to the social and developmental challenges discussed within this document. The impacts of demographic variables that in many respects segment the public on *educational attainment*, *income*, *employment* and other factors remains a salient consideration toward meaningfully addressing these challenges. As such this study aimed to measure the general public understanding of science in South Africa through a *public relationship with science framework* suggested by Reddy *et al* (2009). This approach takes into account *science literacy*; *attitudes*; *interest*; *informdness*; *information sources* and *engagement activities* through the diverse social context of the many South African publicS.

12.2 <u>Research Design and Data Collection</u>

To inform this research, Chapter Two and Chapter Three of the thesis presents an extensive review of the literature that forms the foundation of this study. A detailed historical account of the theoretical development of the main framework for the measurement of the *public understanding of* science is presented, guiding the reader from the early period of *scientific literacy* through to *the public understanding of science* and the *science and society* research paradigms. While there has been much debate as to the theoretical advancement and its influence on measurement practice, Bauer *et al* (2007) notes that "*none of the preceding approaches supersedes the other, but continue to inform enquiry, thereby liberating and expanding the research agenda*".

The work of Miller (1987, 2004) has informed numerous surveys on *scientific literacy* and the *public understanding of science*. As such, this research adopted the foundations of these forerunners, within the design and conceptual framework of this study. Beyond the early work within the *scientific literacy* paradigm, concerned predominantly with knowledge of scientific methods and facts – the evolution of this field quickly became interested in elements of the *public understanding of science* related to *attitudes* and similar influences. As discussed in chapters three and four, the current study defined the South African public understanding of science to comprise of a minimum of six elements that include: *scientific knowledge; attitudes to science; interest; informedness; sources of science information* and *science engagement activities.*

The *individual* as the basic unit of the *public* is seen through an *ecological systems theory* model wherein different levels of the social environment interact and influence the individual, and their ability to engage within areas of science in meaningful ways.

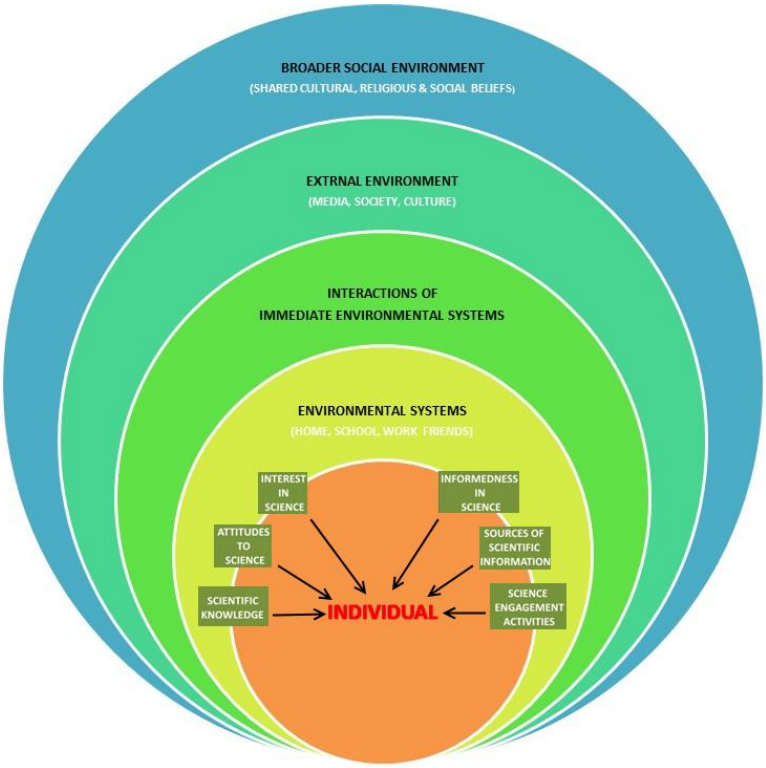


Image 12.1: The 6 elements of the South African public understating of science (SAPUS) in the social context

This model informed the research design and instrument construction in a manner that seeks to understand the various elements contributing to the South African public relationship with science.

With due consideration to the definition of the elements making up the South African public understanding of science, as well as the demographic influences contributing to the contextual environment, an appropriate research questionnaire was designed to implement the fieldwork component of this research project. The questionnaire consisted of six sections, each relating to a single element within the constituent parts of the public understanding of science definition previously discussed (see table 12.1).

Question Section	Response type
SECTION A: Scientific knowledge (9 items)	**True, False**; 3 Point Closed-Ended
SECTION B: Attitude to science (4 items)	**Level of Agreement**; 6 Point Closed-Ended
SECTION C: Interest in science (7 items)	**Level of Interest**; 4 Point Closed-Ended
SECTION D: Informedness about science (7 items)	**Level of Informedness**; 4 Point Closed-Ended
SECTION E: Information sources about science (11 items)	**Frequency of Exposure**; 3 Point Closed-Ended
SECTION F: Participation in science engagement activities (5 items)	**Yes, No**; 2 Point Closed-Ended

Table 12.1: Basic Structure of The PUS Khayabus Survey Module

Each of the six question sets contained a number of closed-ended response items, which was complimented by the collection of demographic and location information for each respondent within the sample. Questionnaire items were adapted from previous work, edited and developed by the author for potential inclusion within the final research instrument. The final instrument contained 43 items, across all of the 6 question sets (see table 12.1). The data gathering component of this study enlisted the field network of a research company to implement a nationally representative survey sample across all 9 South African provinces. The survey was implemented via the *Khayabus Omnibus survey* run by IPSOS South Africa. This was adopted as the most suitable approach considering the logistics and cost associated within conducting survey research of this size and scope.

Following the fieldwork, data processing and cleaning phase, a total sample of 3 486 valid respondents were included in subsequent analysis toward the production of indicators and related data outputs. Appendix one presents the *population* and *sample* characteristics of the final dataset that approximates well to the National Census (2011) as well as *AMPS* (*All Media and Products survey*) data. Population demographics were similarly compared to the National Census data and were suitably show to be consistent with the expected outcomes of this nationally representative sample (see Appendix 1). As a result of these quality assurance procedures, we have argued that the data from the Khayabus Omnibus survey is representative of the overall national population of South Africa, aged 18 years and older.

12.3 Key Outcomes and Recommendations

The purpose of this study was to a) id*entify a set of indicators to measure the South African public understanding of science* and b) to *understand which demographic variables may best serve as predictors to the performance of South Africans* on each of the indicators developed.

We now return to a concluding discussion of the research hypotheses presented in the first chapter of the thesis.

Hypothesis 1a: *South Africans are likely to record low scores on an index of scientific knowledge*

From our review of South African studies on *scientific knowledge* (or by extension "*scientific literacy*") in Chapter Three, it transpired that most studies found South Africans typically answered fewer scientific knowledge items correctly than their international counterparts (Pouris, 1991, 1993; FRD, 1995; Laugksch, 1996; Blankley and Arnold, 2001; Reddy *et al*, 2010).

Laugksch reported that the overall *scientific literacy* rate as measured by his *Test for Basic Scientific Literacy* in 1995 was 36% (Laugksch, 1996). The Foundation for Research Development (FRD) study of 1996, for example, found that on average South Africans answered only about 5 out of the 12 questions in the item set correctly. On a ranking of 20 international studies, employing a similar question set, South Africa was ranked 18th out of the 20 countries. Blankley and Arnold reported, in 2001 that across five items assessing South Africans factual knowledge of science, only 50% were able to provide correct responses, compared to 70% within a comparable American sample (using the same items). Similarly, results from within the 2010 *HSRC - South African Social Attitudes Survey* (SASAS), report that 53.0% of South Africans were able to provide correct responses to 6 scientific knowledge items.

Based on the results of these studies, we formulated the hypothesis that South Africans are typically not very knowledgeable about science. This study essentially confirms this hypothesis. Based on the index of scientific knowledge that we constructed (Chapter Five), slightly more than one third of the respondents (35.7%) were found to have *high* levels of *scientific knowledge*, but 27.3% and 37.0% respectively were found to have only *moderate* and *low* levels of *scientific* knowledge.

At the item level, this is demonstrated by the fact that large proportions of the total sample (more than 40%) got three items wrong. Conversely, only a single item was correctly answered by 50% of the sample (*In the majority of cases, HIV causes AIDS in humans*–67.4%).

		Scientifically Correct	Scientifically Incorrect	D/K
2	Lightning never strikes the same place twice	**32.7%**	45.2%	22.1%
6	Schizophrenia is the same as Multiple Personality disorder	**24.4%**	42.0%	33.6%
5	The price of petrol in South Africa is NOT influenced by the price of crude oil	**35.5%**	40.8%	23.7%
9	The main purpose of the Square Kilometre Array (SKA) radio telescope is to search for extra-terrestrial life	**28.4%**	34.3%	37.3%
8	The earth's climate has NOT changed over millions of years	**41.7%**	33.8%	24.5%
7	The father carries the genetic material that will determine if a baby is a boy or a girl	**46.6%**	33.2%	20.3%
3	South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	**39.5%**	27.3%	33.2%
4	The continents which we live on are continually moving due to forces deep within the Earth	**46.2%**	24.9%	28.9%
1	In the majority of cases, HIV causes AIDS in humans	**67.4%**	18.7%	13.9%

Table 12.2: Survey Results: Science Knowledge items (Khayabus, Wave 2, 2015)

Hypothesis 1b: *South Africans of different demographic categories (race, education, income) are likely to record different levels of knowledgeability about science*

As we have argued in this thesis, knowledge of science varies by demographic variable. Given the huge inequalities and disparities between sub-groups in the South African population, one would expect that belonging to a specific race group, having a certain level of education, living in an urban or rural area, earning high as opposed to low income would be associated with different degrees of knowledgeability about science.

Chapter Three reviewed many of the studies conducted in South Africa and provided detailed insight into the variation in responses to scientific knowledge items, by demographic classifications. Laugksch (1996) commented on the difference between respondents of different races where approximately 50% of white and Indian students were classified as scientifically literate, while only 25% of coloured students and 10% of black students were classified as scientifically literate. Similarly the 1996 FRD study reported that males generally scored higher than females; while it was further noted that a relationship between age, education level and access to media sources increased scores on these questions. Reddy *et al*, in the SASAS 2010 data record that correct response on knowledge questions increase as level of household income increases.

As a result of the findings of these earlier studies, the hypothesis was formulated, that South Africans would differ in recorded levels of *knowledgeability*, by demographic classification. This hypothesis was validated in the results of the *science knowledge index* where variations were recorded for respondents from different demographic groups (see table 12.3). Results at item-level reflect similar patterns across different demographics.

	LOW SCIENTIFIC KNOWLEDGE	MODERATE SCIENTIFIC KNOWLEDGE	HIGH SCIENTIFIC KNOWLEDGE	N	Asymptotic Significance (2-sided)	Pearson's R
NATIONAL	**37.0%**	**27.3%**	**35.7%**	**3 486**		
RACE	**N = 3 188**				**RACE**	
BLACK	39.6%	27.3%	33.1%	**2 273**	p < 0.001	-0.039
WHITE	24.3%	26.7%	49.0%	**404**		
INDIAN / ASIAN	38.6%	15.8%	45.6%	**114**		
COLOURED	34.3%	31.2%	34.5%	**397**		
HOUSEHOLD INCOME	**N = 2 042**				**HOUSEHOLD INCOME**	
LOW	43.2%	24.9%	31.9%	**1 432**	p < 0.001	0.175
MODERATE	27.5%	28.5%	44.0%	**466**		
HIGH	18.8%	28.5%	52.8%	**144**		
EDUCATION	**N = 3 188**				**EDUCATION**	
PRE-MATRIC	44.1%	24.0%	31.9%	**1 197**	p < 0.001	0.124
MATRIC COMPLETED	34.6%	30.4%	35.1%	**1 476**		
POST-MATRIC	27.4%	26.2%	46.4%	**515**		

Table 12.3: Survey Results: Science Knowledge Index by selected demographics

The outputs of the multinomial logistic regression analysis similarly revealed that the best predictors of outcomes on the *science knowledge index* were respondent *race classification*; *household income* and *educational attainment* level. These results show that respondents with *lower household income* levels were only 31.2% as likely as those from *high income household* to score high on the scientific knowledge index. Similarly, respondents with a *pre-matric* educational attainment level were only 58.2% as likely as those with *post-matric* education to appear in the *moderate* scientific knowledge group, when compared to the *low scientific knowledge* group.

Likelihood Ratio Tests				
	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1829.512	.000	0	.
RACE	**1842.536**	**13.024**	**6**	**.043**
EDUCATIONAL ATTAINMENT	**1849.143**	**19.631**	**4**	**.001**
HOUSEHOLD INCOME	**1860.721**	**31.209**	**4**	**.000**

Table 12.4: Multinomial logistic regression result: Predictors of outcomes on Science Knowledge Index

Hypothesis 2a: *South Africans are more likely to hold positive than negative attitudes towards science*

Blankley and Arnold (2001) had measured South Africans' attitudes to science using the *Index of Scientific Promise and Reservation*. The results of their investigations revealed that, while respondents did show some *reservation* with regards to certain aspects of science, in general South Africans had demonstrated a generally positive attitude to science (Index ratio: 1.28). This compared favourably with international studies, ranking South Africa 4th, behind Italy (1.28); Canada (1.29) and the USA (1.89). In his 2001 study, Pouris reports that respondents generally indicated strong agreements to statements of scientific promise (greater than 70%) while an average of 63% of respondents agreed with the scientific reservation statements. In the 2010 SASAS survey, the HSRC reports that South Africans continue to display more positive than negative attitudes to science. Comparison of the output of the Promise/Reservation Index with international surveys shows that South Africa obtained an index ratio of 1.20; India was 0.80; while the USA achieved a ratio of 1.70. The results of the 2013 SASAS survey module on the public understanding of science similarly reports greater positive attitudes to science among South Africans (see Chapter Three).

Based on the findings of these studies and numerous empirical research reports on attitudes to science in South Africa, this research formulated the hypothesis that *South Africans are more likely to hold positive than negative attitudes towards science*. This hypothesis is supported by the findings of this study. At the item level, an average of 58.2% of respondents agreed with *scientific reservation* items, while 70.3% of the sample agreed with *scientific promise* items.

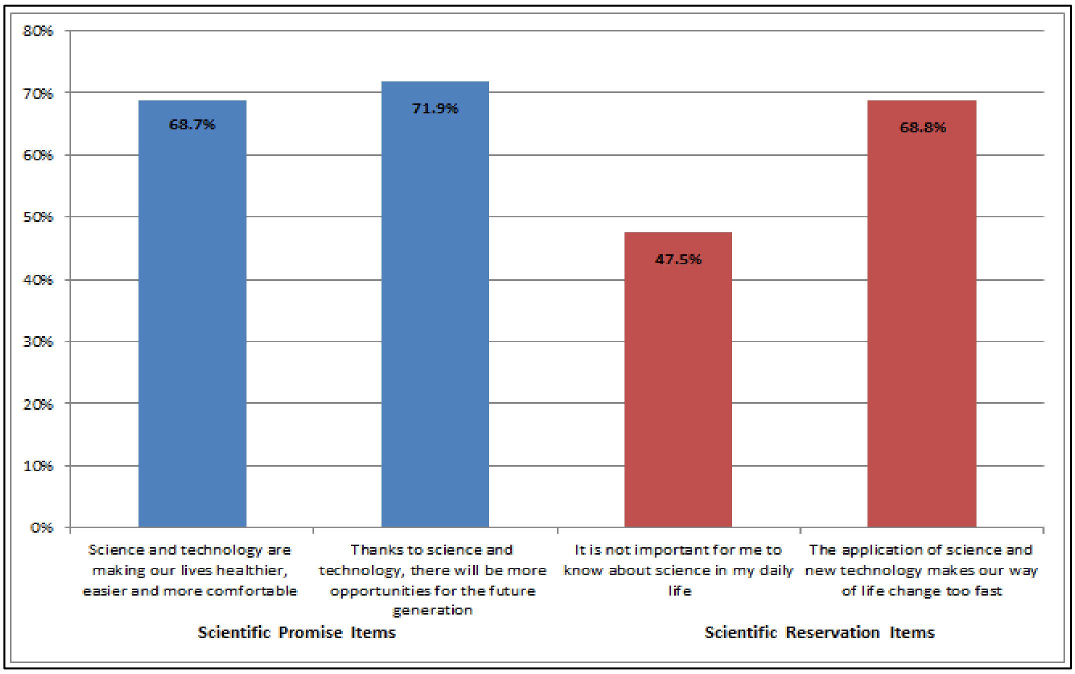


Chart 12.1: Survey Results: Attitude to Science items (Khayabus, Wave 2, 2015)

Similarly, the outcome of the *index of scientific promise and reservation* produced a ratio of 1.21 for the current study, again affirming the hypothesis that South Africans *hold more positive than negative attitudes to science.* Finally, within the *index of attitudes to science*, a larger proportion of respondents were classified as having a *positive attitude* to science (44.1%) when compared to those recording negative attitudes (19.4%).

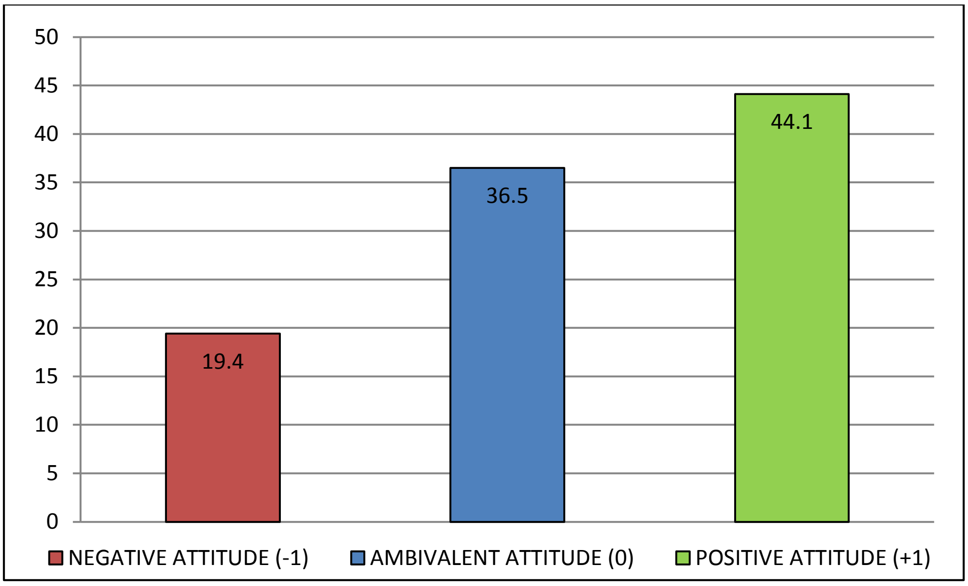


Chart 12.2: Index outcome: Attitude to Science

Hypothesis 2b: *South Africans of different demographic categories are likely to differ in their attitudes towards science*

Previous South African empirical studies about attitudes to science have highlighted the association between such attitudes and different demographic variables. Pouris (1993) found that respondent language group showed some association with attitude to science. English speaking respondents, most frequently expressed a lower positive attitude toward science, while black respondents reported being more optimistic about science and its impact on daily life. The FRD (1996) study highlighted similar patterns of demographic variation in attitudes to science. In that study, males (68%) generally indicated a marginally more positive appreciation of science compared to females (64%), while Indians showed more positive attitudes (94%) compared to white (93%), coloured (61%) and black respondents (59%).

In 2010 Reddy *et al reported* disaggregated attitudinal data from within the SASAS survey by educational level, age and gender. They report that there were no striking variations for attitudes to science with respect to gender; however age was shown to demonstrate a significant relationship with attitudes toward science. Younger participants (16-19 years old) showed a greater sense of scientific promise and consequently more positive attitudes toward science compared to older age groups. Similarly, as educational level increased so too do positive *attitudes to science* and a greater sense of scientific promise, compared to respondents reporting lower academic attainment levels. These results were again reflected in the SASAS 2013 data, where age, educational attainment level and LSM (living standard measure) were shown to have a significant relationship with measures of attitudes to science.

As a result of these previous empirical findings (reported in Chapter Three), hypothesis 2b was formulated about the relationship between demographic factors and attitude to science. Survey results presented in Chapter Six indicate that while there is some variability across demographics, the association with attitude to science was not significant for most of the demographic variables. *Gender*; *geographic location*; *educational attainment* and *age* were not found to be associated with differences in attitude towards science. However, respondent *race* was found to be significantly associated with attitude to science, with more coloured respondents (52.0%) recording positive attitudes to science compared to white (48.4%) and Indian / Asian (46.2) and black (41.9%) respondents.

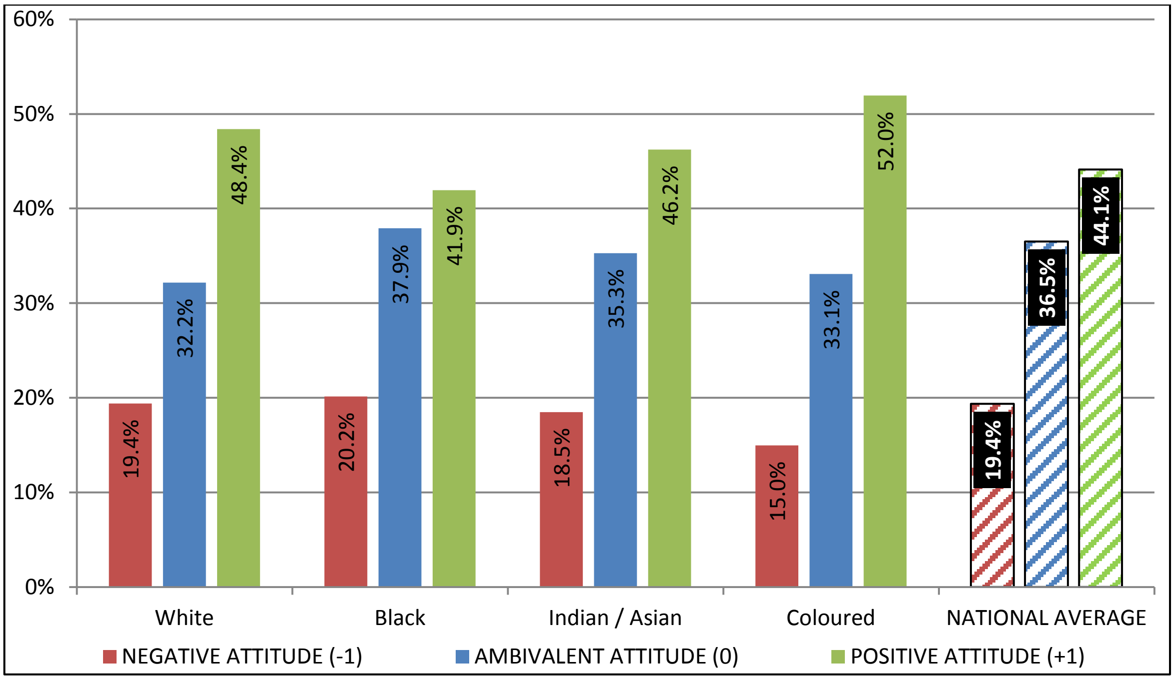


Chart 12.3: Index of Attitude to Science by race

The multinomial logistic regression analysis also revealed that the *race* variable was the only significant predictor of respondent outcome classification on the *Index of attitudes to science*. This result indicates that black and white respondents were only 61% as likely as coloured respondents to display positive, compared to negative attitudes to science.

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1906.285	.000	0	.
RACE	**1925.212**	**18.927**	**6**	**.004**

Table 12.5: Multinomial logistic regression result: Predictors of outcomes on Attitudes to science Index

With the exception of "race" no other demographic factor was found to differentiate amongst our respondents as far as attitudes towards science are concerned. This can possibly be attributed to the fact that two out of every five South Africans were found to be positive about science (as compared to only one out of five who hold negative attitudes towards science). Stated differently: the fact that we found that the largest single proportion of our respondents are positive about science cuts across most of the demographic factors included in our study. However as noted by Reddy *et al* (2013) as well as Guenther and Weingart (2016), South Africa does present a *unique profile* with regards to attitudes to science. This in particular requires further investigation to best understand the complex dynamics of South Africans attitudes to science.

Hypothesis 3a: *South Africans are more likely to record moderate than high levels of interest in science*

Reviewing the limited number of studies conducted in South Africa in the last 20 years has revealed that generally South Africans report a moderate level of interest in science. Pouris (2001) surveyed 1 000 individuals and measured interest in 8 areas of science. Within this study, the average level of interest across the 8 items was found to be 34.5%. Blankley and Arnold (2001) similarly reported that across a 4-item interest in science question, 48.1% of respondents indicated interest in any of the science areas included. In the 2013 SASAS survey, Reddy and colleagues measured an average interest in science among South Africans, across 8 items to be 22.7%.

As a result of these findings, we formulated the hypothesis that South Africans are more likely to present *moderate* than *high* interest in science. The results support this hypothesis. While a large proportion of the sample indicated *no interest* (41.5%); 30.9% indicated they were *moderately interested*, while 21.2% indicated they were *very interested* in the 7 areas of science.

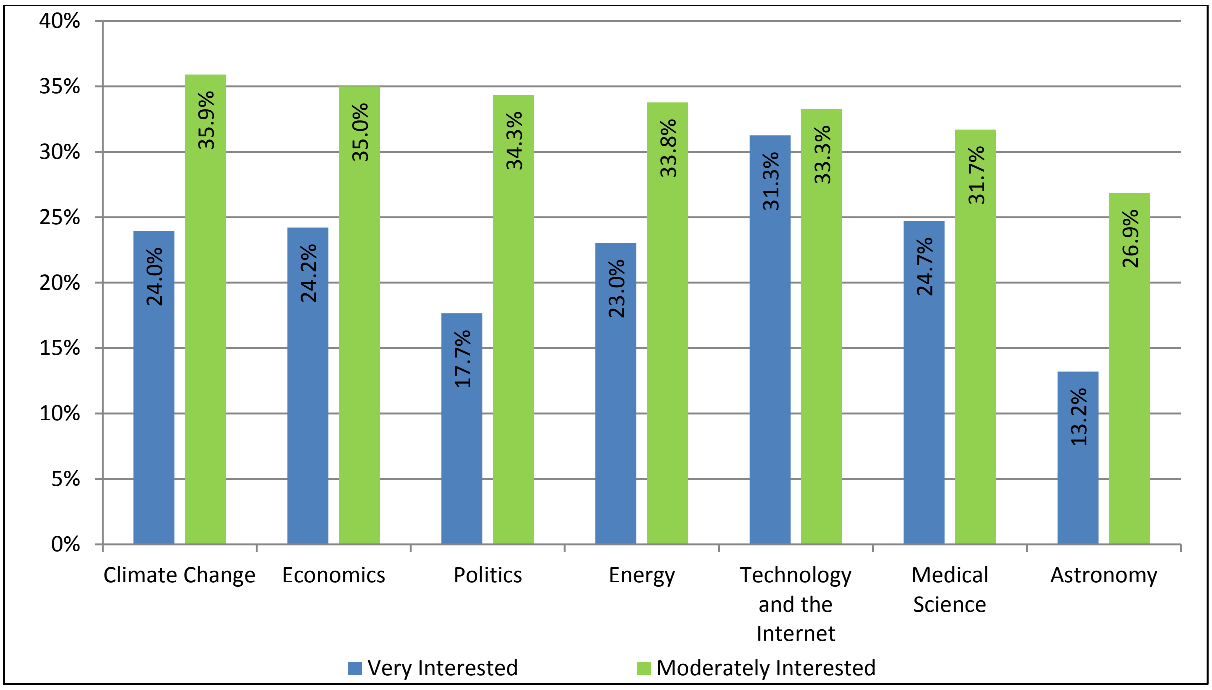


Chart 12.4: Survey Results: Interest in Science items (Khayabus, Wave 2, 2015)

With response for *no interest* removed (chart 12.4), at the item level, more items recorded a *moderately interested* response, rather than a *very interested* response. With the exception of the items relating to *technology and the internet* as well as *medical science*, in every other item, the response within the *moderately interested* category was more than 10% higher than within the *very interested* option.

Hypothesis 3b: *South Africans of different demographic categories are likely to differ in their levels of interest in science*

Previous scholarship notes that Interest in science presents some variation as a result of various demographic factors. Blankley and Arnold (2001) report that while the average interest within their sample was 48.1%, this was highest among black respondents (49.3%); followed by white (47.9%); coloured (42.0%) and Indian / Asian (40.3%) respondents. Pouris (2001) reported gender-based variations for interest in science, where across 8-items, males (39.4%) reported higher interest in the 8 scientific areas compared to females (30.8%). Reddy *et al* (2013) report that younger respondents reported higher interest across 8 science-interest items, compared to older respondents, while those within higher education and LSM groups similarly reported higher interest in science.

The hypothesis above was validated within the results that found South Africans did differ on the interest in science measure across three demographics.

	LOW INTEREST	MODERATE INTEREST	HIGH INTEREST	N
NATIONAL	**32.7%**	**34.9%**	**32.4%**	**2 640**
RACE	N = 2 640			
BLACK	31.4%	34.7%	33.8%	**1 934**
WHITE	28.8%	32.6%	38.6%	**337**
INDIAN / ASIAN	16.7%	47.2%	36.1%	**72**
COLOURED	49.2%	35.4%	15.5%	**297**
GEOGRAPHIC LOCATION	N = 2 640			
URBAN	31.5%	33.5%	35.0%	**1 824**
RURAL	35.4%	38.0%	26.6%	**816**
EDUCATION	N = 2 640			
PRE-MATRIC	40.1%	34.7%	25.2%	**926**
MATRIC COMPLETED	30.4%	36.3%	33.3%	**1 252**
POST-MATRIC	24.0%	31.6%	44.4%	**462**

	Asymptotic Significance (2-sided)	Pearson's R
RACE	$p < 0.01$	-0.133
GEOGRAPHIC LOCATION	$p < 0.01$	-0.071
EDUCATION	$p < 0.01$	0.153

Table 12.5: Survey Results: Interest in science Index by selected demographics

Variations in recorded level of interest by *race*, *geographic location* and *educational attainment* level were shown to be statistically significant (see table 12.5). Coloured respondents; those who live in the rural areas and those with pre-matric education, recorded significantly lower levels of interest in science when compared to other categories within each demographic. Results at item-level reflect similar patterns for demographic classifications and were reported in detail within Chapter Seven.

The outputs of the multinomial logistic regression analysis presents further confirmatory results in identifying *race*, *geographic location* and *educational attainment* level as the best predictors of outcomes on the *interest in science index*.

Likelihood Ratio Tests				
	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1675.958	.000	0	.
GEOGRAPHIC LOCATION	1687.602	11.643	2	.003
EDUCATIONAL ATTAINMENT	1710.237	34.279	4	.000
RACE	1702.917	26.959	6	.000

Table 12.7: Multinomial logistic regression result: Predictors of outcomes on interest in science Index

The regression results show that respondents with pre-matric education are only 61% as likely as those with a post-matric education to appear in the moderate interest category, compared to the low interest category. Similarly, urban respondents are 1.5 times more likely to appear in the high interest group than rural respondents, when compared to the low interest group. As a result of the low overall interest in science within the coloured sub-sample, all other race classifications were found to be 3 times more likely than coloured respondents to appear in the high interest compared to the low interest outcome. This was highest among Indian / Asian (3.74); followed by white (3.28) and then black (3.14) respondents

Hypothesis 4a: *South Africans are more likely to record low than high levels of informedness about science*

From the literature review it emerged that South Africans generally report not being well-informed about areas of science. Pouris (2001) included 8 areas of science and asked respondents to indicate their *level of informedness* for each item. While there was significant variation in level of informedness within each item, the average level of informedness across the 8 items was 18.6%. Reddy *et al* (2013) similarly report that in the 2013 SASAS survey, two-thirds of South Africans more often reported not being *very well informed* or *not at all informed* about science, compared to one third that reported being *well informed*.

As a result of the above we formulated the following hypothesis: *South Africans are more likely to record low than high levels of informedness about science*. Our survey confirms this hypothesis, as we found that only 13.7% of respondents said that they are very *well informed*, while 28.2% and 50.5% report being *moderately well informed* or *not well informed*, respectively. These latter two response categories account for 78.7% of total responses (n = 3 486).

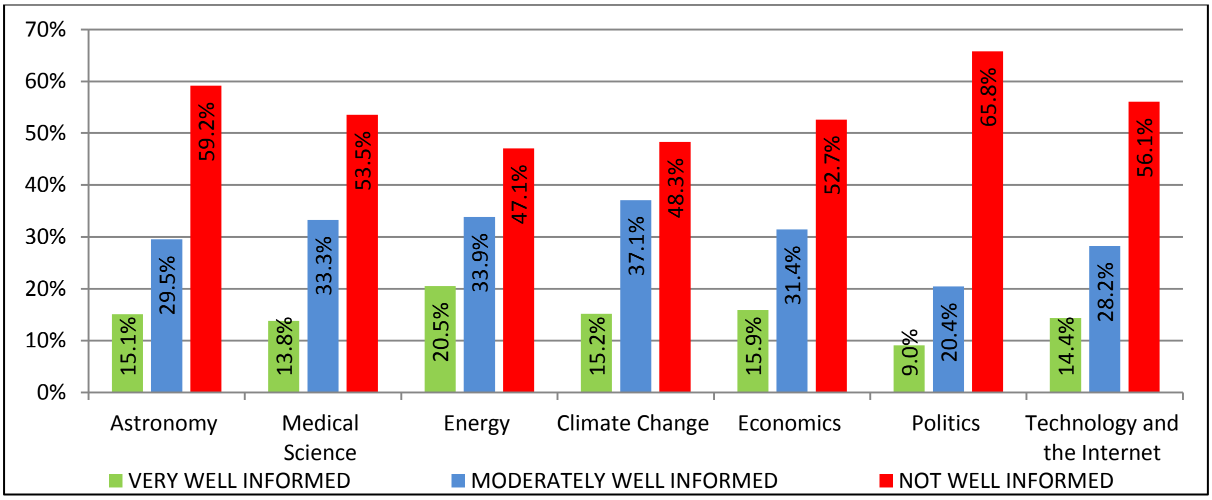


Chart 12.6: Survey Results: Informedness about Science items (Khayabus, Wave 2, 2015)

Confirming the assertion that *South Africans are more likely to record low than high levels of informedness about science,* chart 12.6 presents the results at item level, demonstrating the higher proportion of *moderately well informed* and *not well informed* responses, compared to the *very well informed* option.

Hypothesis 4b: _South Africans of different demographic classifications are likely to differ in their levels of informedness about science_

Level of informedness is generally a self-assessment by respondents on how well they understand a particular area of science. While limited empirical work has been done within this particular area, Pouris (2001) showed that informedness among South Africans did show some variation by demographic variable. Across 8 areas of science, also included in the *interest in science* assessment, an average of 22.1% of males report being *very well informed*, while only 15.6% of females provided the same response. Pouris further reports, that younger and more educated respondents record higher levels of informedness, compared to other respondents.

Based on this, the current study formulated the hypothesis that *South Africans of different demographic classifications are likely to differ in their levels of informedness about science*. This study confirmed this hypothesis, where response variations were recorded for respondents from different demographic groups (see table 12.8). Results at item-level reflect similar patterns for demographic classifications and were reported in detail within Chapter Eight and Chapter Eleven of this thesis. The variables for *race*, *geographic location*, *educational attainment* and *respondent age* were statistically associated with the reported *level of informedness* among the sample.

	LOW INFORMEDNESS	MODERATE INFORMEDNESS	HIGH INFORMEDNESS	N	Asymptotic Significance (2-sided)	Pearson's R
NATIONAL	**32.8%**	**33.4%**	**33.7%**	**3 346**		
RACE	**N = 3 346**				**RACE**	
BLACK	33.6%	32.2%	34.3%	**2 410**	**p < 0.001**	**-0.120**
WHITE	21.2%	32.7%	46.1%	**401**		
INDIAN / ASIAN	43.7%	28.6%	27.7%	**119**		
COLOURED	36.5%	43.0%	20.4%	**416**		
GEOGRAPHIC LOCATION	**N = 3 346**				**GEOGRAPHIC LOCATION**	
URBAN	27.9%	34.9%	37.2%	**2 232**	**p < 0.001**	**-0.146**
RURAL	42.6%	30.6%	26.8%	**1 114**		
EDUCATION	**N = 3 346**				**EDUCATION**	
PRE-MATRIC	43.3%	32.3%	24.4%	**1 278**	**p < 0.001**	**0.229**
MATRIC COMPLETED	29.6%	35.1%	35.3%	**1 546**		
POST-MATRIC	16.5%	31.2%	52.3%	**522**		
AGE	**N = 3 332**				**AGE**	
<20 YEARS	34.3%	27.1%	38.6%	**166**	**p < 0.01**	**-0.050**
20-29 YEARS	32.2%	33.3%	34.5%	**1 075**		
30-39 YEARS	31.9%	34.0%	34.1%	**913**		
40-49 YEARS	29.8%	35.4%	34.8%	**573**		
50-59 YEARS	33.0%	33.6%	33.4%	**351**		
60+ YEARS	45.3%	31.5%	23.2%	**254**		

Table 12.8: Survey Results: Informedness about science Index by selected demographics

In particular, white, urban, well-educated and younger respondents recorded higher levels of informedness about science, compared to respondents within other demographic classifications and sub-classifications.

Results from the multinomial logistic regression show that the best predictors of respondent outcome on the index of informedness about science are: *race*; *geographic location*; *age*; *educational attainment*; *employment status* and *household income*.

Likelihood Ratio Tests				
	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1909.346	.000	0	.
RACE	1952.898	43.552	6	.000
GEOGRAPHIC LOCATION	1935.669	26.323	2	.000
AGE	1927.588	18.242	10	.051
EDUCATION	1958.322	48.976	4	.000
EMPLOYMENT STATUS	1920.439	11.093	4	.026
HOUSEHOLD INCOME	1918.291	8.945	4	.063

Table 12.9: Multinomial logistic regression result: Predictors of outcomes on informedness about science Index

Respondents who live in the urban areas as well as those employed were 1.6 times more likely to be 'classified' as belonging to the *moderate informedness* group than rural respondents, when compared to the low *informedness* group. Similarly, white respondents were twice as likely to appear in the *high informedness* group as coloured respondents, when compared to the low *informedness* group. Younger respondents were three times as likely to appear in the *high informedness* group, than older respondents, compared to the low informedness group.

Hypothesis 5a: <u>*South Africans overall are more likely to favour "old technologies" (Radio, TV and Print) compared to "new technology" (online) information sources*</u>

Our review of the literature revealed that very few empirical studies in South Africa investigated sources of scientific information. However, two studies did include questions relating to science information sources, one in 2001 and another in 2013. Pouris included four science information source items in his 2001 investigation into *Interests, Public Understanding and Sources of* [science] *Information in South Africa*. In 2001, he reports that the most frequently accessed science information source was *magazines* (77%), followed by *television* (66%); *newspapers* (57%) and then *computer-based* information sources[145] (19%). Taking the time-period into account (2001) it is no surprise that only 19% of respondents report any form of digital information source within the Pouris study. This indicates a greater concentration of science information sources within the *old media* classifications *(radio, TV and print*). Reddy *et al* in the 2013 SASAS survey similarly investigated sources of science information, adopting seven science information sources. Results from this survey indicate that South Africans, in 2013 most frequently reported *television* (50%); followed by *radio* (41%); *newspapers* (27%); *the internet* (24%); *other people* (24%); *books / magazines* (23%) and *public spaces* (14%). As a result of the *internet* being a single category (not disaggregated by information source), it is apparent that *old media* classifications *(radio, TV and print*) continue to be the most important sources of science information for South Africans.

With advances in media availability, access, infrastructure and public access facilities and based on the evidence in prior research, this study proposed to test the hypothesis that *South Africans overall are more likely to favour "old technologies" (radio, TV and print) compared to "new technology" (online) information sources*. Across the 11 science information sources[146] in this study, *old technologies* include: Radio; Satellite Television; Free-to-Air Television; Books / Magazines and Newspapers. *New technologies* include: Blogs; Institutional Websites; News Websites and Social media. The survey has confirmed our hypothesis. Nearly 80% of respondents reported using an old *technology* more frequently as a science information source, while 65.4% of respondents reported using new *technology* (see chart 12.7).

[145] In 2001, it is likely that this item did not refer to the present day internet, but was likely removable media, CD-roms and other home-based information software (encyclopaedias etc.) – though DR Pouris is not specific as to what is included in this category.
[146] *Human information* sources (Government Announcements and Other people) were not considered in this analysis.

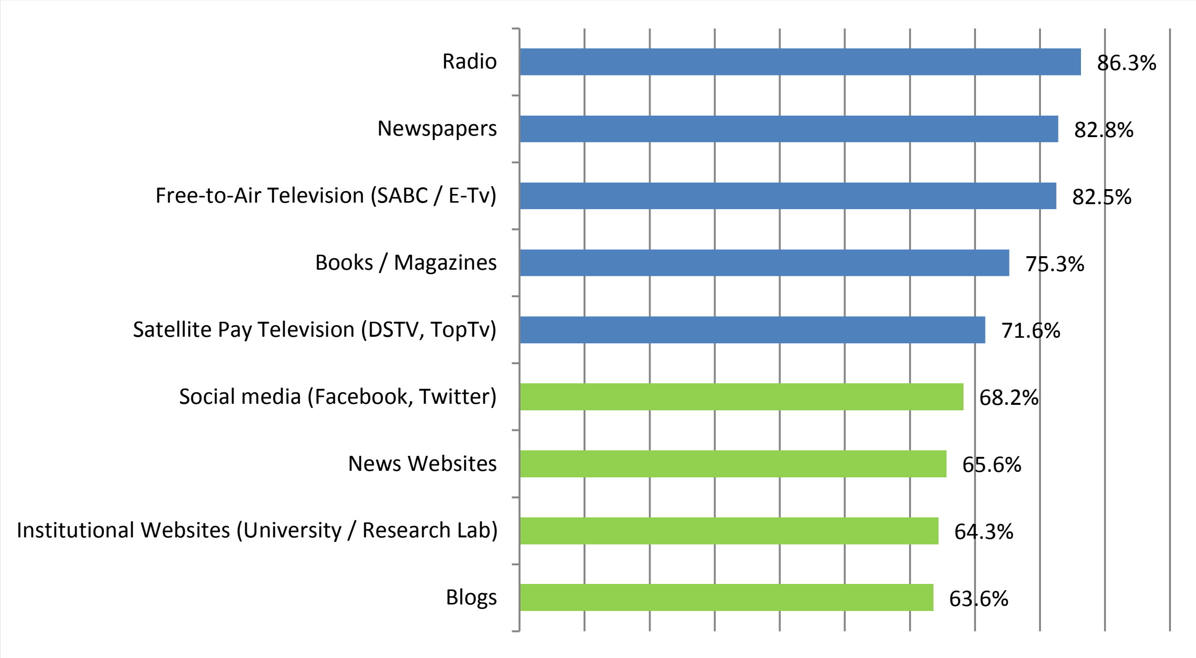


Chart 12.7: Survey Results: Science information source items (Khayabus, Wave 2, 2015)

At the item-level results (Chapter Nine), it is clear that *radio*, *newspapers* and *television* remain the most important science information source for the majority of South Africans. While the availability and access to online material and services is expanding, South Africans currently appear to favour *old technologies*, over *new technologies* as a source of science information.

Hypothesis 5b: *South Africans of different demographics are likely to differ as far as their preferred sources of science information are concerned*

The SASAS (2013) survey presented results on the source of science information, disaggregated by age; education and LSM (living standard measure). Overall, this study reported that younger respondents access a wider variety of information sources more frequently compared to older respondents. However, the survey did highlight that *radio* presented similar usage / access patterns across all age groups, while *print* information sources were increasingly reported by older respondents. Respondents who are better educated reported using a greater number of science information sources, including *books / magazines* and the *internet*. Similarly, respondents within higher LSM categories reported using a greater number of science information sources, with *television*, *newspapers* and the *internet* recording the highest selections. Moderate and low LSM respondents selected *television, radio* and *other people*, while those within the low LSM groups favoured *radio*.

Based on the above evidence, and similar findings from international studies, we hypothesized that *South Africans of different demographic classifications are likely to differ as far as their preferred sources of science information are concerned*. Again this hypothesis was corroborated by our study.

	OVERALL NATIONAL RANKING ORDER				
	Radio	**Newspapers**	**Free-to-Air TV**	**Other people**	**N**
NATIONAL	**86.3%**	**82.8%**	**82.5%**	**78.8%**	**3 486**
Ranking varies within demographic groups					
RACE	**N = 3 486**				
BLACK	85.9%	81.4%	81.0%	75.9%	**2 523**
WHITE	92.2%	92.9%	91.2%	93.6%	**408**
INDIAN / ASIAN	94.2%	93.4%	93.4%	91.7%	**121**
COLOURED	81.3%	78.6%	80.2%	77.9%	**434**
GEOGRAPHIC LOCATION	**N = 3486**				
URBAN	88.6%	86.3%	85.2%	82.4%	**2 297**
RURAL	82.0%	76.1%	77.3%	71.8%	**1 189**
EDUCATION	**N = 3486**				
PRE-MATRIC	81.7%	74.4%	75.8%	70.9%	**1 369**
MATRIC COMPLETED	88.5%	86.9%	85.6%	82.4%	**1 578**
POST-MATRIC	91.8%	92.4%	90.5%	88.1%	**539**
AGE	**N = 3 472**				
<20 YEARS	86.5%	80.0%	84.7%	78.2%	**170**
20-29 YEARS	86.6%	84.1%	84.0%	80.7%	**1 101**
30-39 YEARS	85.7%	82.8%	81.6%	78.1%	**956**
40-49 YEARS	88.0%	84.8%	84.1%	79.8%	**598**
50-59 YEARS	84.9%	81.5%	79.8%	78.5%	**372**
60+ YEARS	85.1%	76.4%	77.8%	71.3%	**275**

Table 12.10: Survey Results: Science information source by selected demographics

As far as *sources of science information* is concerned, *race*; *geographic location*; *educational attainment* and *age* were found to be statistically significant. While most all demographic groups selected either *radio*, *newspapers*, *television* or *other people* as the top four information sources, some variation in the ranking order did emerge across demographic sub-samples. White respondents preferred information sources such as other *people* followed by *newspaper*; *radio*; *satellite pay television*. Black respondents selected *radio*; followed by *newspapers*; *free-to-air television* and then *other people*. Among the coloured sub-sample the selections were as follows: *radio*; followed by *free-to-air television*; *newspapers* and *other people*. While within the Indian / Asian sub-sample the preferred information sources were: *radio*; followed by *newspaper*; *free-to-air television* and *other people*. The information source patterns within the rural / urban classifications included: *radio*; followed by *newspapers*; *free-to-air television* and *other people*, with the rural sample ranking *free-to-air television* higher than *newspapers*. Educational attainment classifications ranked information sources as follows: *Pre-matric*: *Radio, Free-to-Air Television, Newspapers* and *Other people*; *Matric completed*: *Radio; Newspapers; Free-to-Air Television* and *Other people*; *Post-matric*: *Newspapers; Radio; Free-to-Air Television* and *Satellite Pay Television*. Age classifications showed some commonalities in selections. Respondents younger than 20 years and older than 60 years selected the top four items in the following order: *Radio; Free-to-Air Television; Newspapers* and *Other people.*

Respondents aged 20 to 59 years selected thee following: *Radio; Newspapers; Free-to-Air Television* and *Other people*.

While the selections of the type of information source remained within four categories, the preference of science information sources among the sample does appear to differ within demographic variables.

Previous studies on the public understanding of science did not provide adequate evidence on *science engagement activities* to enable us to formulate specific hypotheses. Hence, we formulated the more exploratory hypotheses as below:

Hypothesis 6a: <u>*South Africans are more likely to record low than high levels of attendance at science engagement activities*</u>

Based on the outcomes of this survey, there is strong evidence that, in general South Africans do not attend science engagement activities with great frequency. Chart 12.8 presents the output of the science engagement items. Within the 3 345 valid responses, only 11.5% (950) attended a science engagement activity within the preceding 12 month period.

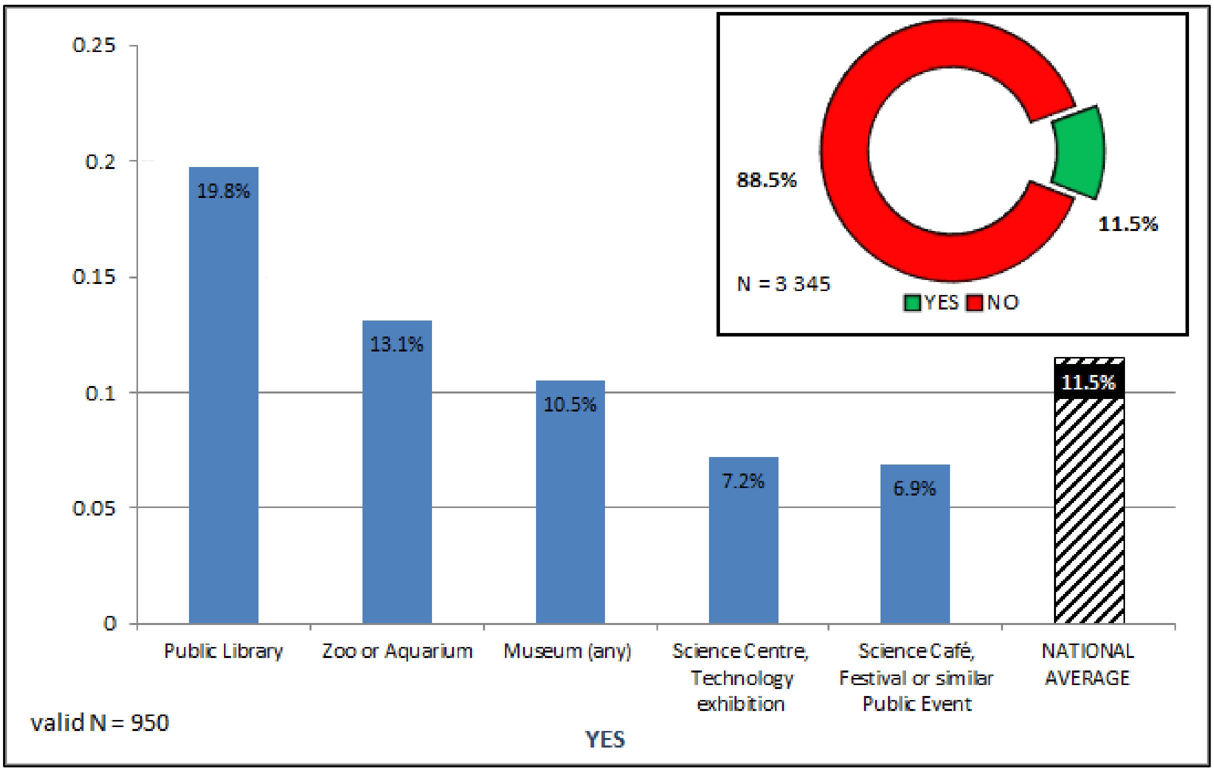


Chart 12.8: Survey Results: Science engagement items (Khayabus, Wave 2, 2015)

Of the respondents that did report attending some science engagement activity, the majority attended a *public library* (19.8%) followed by going to a *zoo or aquarium* (13.1%) or a *museum*

(10.5%). Very few respondents attended any of the other science engagement activities. This result points to a general low engagement in science activities.

Hypothesis 6b: *South Africans of different demographic classifications are likely to differ in the frequency of attendance at science engagement activities*

As discussed in Chapter Ten, respondents from different demographic classification groups record varying levels of attendance at science engagement activities. Table 12.11 details the response within the science engagement index, by demographic classifications.

	LOW ENGAGEMENT	MODERATE ENGAGEMENT	HIGH ENGAGEMENT	N	Asymptotic Significance (2-sided)	Pearson's R
NATIONAL	**48.2%**	**23.6%**	**28.2%**	**2 536**		
RACE	N = 950				**RACE**	
BLACK	52.0%	22.3%	25.6%	**613**	**p < 0.001**	**-0.128**
WHITE	32.8%	23.2%	44.1%	**177**		
INDIAN / ASIAN	40.0%	28.0%	32.0%	**25**		
COLOURED	52.6%	28.9%	18.5%	**135**		
GENDER	N = 950				**GENDER**	
FEMALE	52.0%	23.8%	24.2%	**479**	**p < 0.05**	**-0.092**
MALE	44.4%	23.4%	32.2%	**471**		
GEOGRAPHIC LOCATION	N = 950				**GEOGRAPHIC LOCATION**	
URBAN	44.4%	23.1%	32.5%	**728**	**p < 0.001**	**-0.174**
RURAL	60.8%	25.2%	14.0%	**222**		
EDUCATION	N = 950				**EDUCATION**	
PRE-MATRIC	59.3%	26.0%	14.7%	**204**	**p < 0.001**	**0.208**
MATRIC COMPLETED	49.2%	24.4%	26.4%	**508**		
POST-MATRIC	36.6%	19.7%	43.7%	**238**		

Table 12.11: Survey Results: Science engagement activities by selected demographics

Among the 950 respondents that reported attendance at science engagement activities, 48.2% were classified within the *low engagement* group (attended one activity); 23.6% were within the *moderate engagement* group (attended two activities) while 28.2% were classified within the *high engagement* group (attended three or more activities). *Race*, *gender*, *geographic location* and *educational attainment* were all found to be associated with engagement in science. More black and coloured respondents were classified as the *low engagement* group compared to Indian / Asian and white respondents. Females, respondents in rural areas as well as those with lower educational attainment were similarly shown to attend fewer science engagement activities. This result validates the hypothesis of a differential science engagement attendance pattern for various demographic classifications.

The results of the study demonstrate the importance of demographics in understanding public understanding of science measures. While some of the impacts of demographic classifications are *alterable* – such as quality of education; access to engagement activities etc. – other factors related to the interactions with race categories remain complex and less alterable.

The clear message to communicators of science and science policy leaders is that a *one-size-fits-all* approach is not ideal within the South African context. Within race, gender, rural / urban and age classifications there remain variations in access to resources that influence how well sub-populations within these classifications perform on such assessments. Beyond the short terms focus on indicator outcomes, the creation of real change within these underserved segments of the South African population remains a key focus.

These findings may have significant implications for the national science policy agenda, wherein a shifting of focus from *funders* and *performers* of science needs to be redistributed to further include the general publics as *consumers* of scientific information. While there have been efforts toward the development of a suitable science engagement policy framework, the role of the general South African public has not been central to these policy formulations. This realignment of the national policy direction to allow for the public to make a greater contribution would naturally rely on a citizenry suitably skilled and informed toward substantially advancing these policy discussions. However a *perceived deficiency* at either end of this value chain need not necessarily allow for the exclusion of these equal partners in the future growth of South Africa. Serving the public interest requires input from the public – this must be the foundation of future policy formulations that influence the South African public understanding of science.

12.4 Limitations of this Study

The development of the indicators in this study required the use of a large sample toward ensuring that the outputs are reflective of the national public understanding of science. The design and implementation of a nationally representative survey sample ensured a consistent link to National Census and allowed for generalisability to the population. However despite this the study focused on a limited scope to highlight the six functional areas of the South African public understanding of science (PUS) related to indicator development. This ultimately resulted in the focus of the study being narrowed to a limited degree of focus, despite the wealth of information gathered during the data collection phase.

The literature review identifies the broad scope of this research area; however as a result of the aims of this particular study, a deliberate narrowing of the potential scope of this research was employed. Cost considerations were to a large extent the most severe limitation on the questionnaire items included, however despite this a reasonable degree of coverage within the questionnaire as well as the objectives of this research study was included and ultimately achieved.

An extensive review of the international literature has been undertaken and summarized within the opening chapters of this document. However despite this a limited number of empirical studies with specific reference to the public understanding of science in the South African context are available. This relates specifically to the implications of racial, cultural and developmental economics within this context and remains far removed from the volumes of measurement literature emanating from with the developed world.

The development of items for inclusion in this research maintained a focus on international comparability, while attempting to suitably localise the content such that it remains relevant for the intended population. It was considered more important to ensure that the content of the science knowledge assessment reflected the local context of measurement to ensure the relevance of the outcome indicators produced. Further research into the selection of items and international comparability would be required toward addressing this issue that would impact many developing contexts implementing surveys of this nature. Despite these challenges, every effort was made to ensure the goals of this research project were met, while maintaining a relative degree of international comparability.

South Africa is not a homogenous society and as a result the focus of this research was to understand the role played by demographic variables on the general public understanding of science. The noted variation within the general public opens the discussion for the notion of the many South African public**S**. This is further complicated by the varying degrees of ability as a result of the influence of access to education; income and related variables discussed in this document. Understanding the many public**S** opens the discussion on the level of difficulty that assessments of this nature should aim to achieve. Standards that are too high or too low would result in inaccurate results and indices that do not provide an accurate picture of the South African public understanding of science. Benchmarking then remains crucial; to effectively position the level of questions within such assessment toward attaining a true reflection of PUS in South Africa.

An extensive review of the theoretical and empirical scholarship within this field was performed; however an important outcome is the lack of suitable literature on public understating of science indicator development. Perhaps a broader reading of the literature on social indicator development may be required toward adopting a multidisciplinary approach to enhance measurement outcomes within this field.

As discussed within the indicator development chapter, the *cut-off scores* on the indicator classifications were based on *empirically* driven *cut-off* and not *theoretically* driven cut-offs. These may result in the index not being as precise as it could be. It remains critically important to note here that there is a persistent lack of literature guiding such efforts, that in the absence of better guidance, this research adopted the most justifiable approach toward the development and construction of the indices within this study.

The scope of the current study was amended and as a result, two points within the initial research proposal were not operationalised. The first was a planned assessment on potential variations in South Africans' attitudes to *general* science issues versus *specific topical issues* (nuclear technology or fracking – shale gas exploration). While this was a particular area of interest, the number of items required to meaningfully explore this question was not financially viable within the funding structure and did not contribute toward the primary goal of *indicator development*. As a result this research question was omitted within the final study design. A further item within the original research proposal was to reproduce selected international PUS indicators within South African data (example: the *Science Culture Index*; *Cultural Distance of Knowledge Concepts*). Similar to the previous point, the research supervisor advised that these pursuits, though valuable, were not contributing to the specific indicator set that is the outcome of this research and as a result this aspect was no longer included within the study outputs.

12.5 Future Research Directions

The volume of data within this research has highlighted a few areas requiring further research investigation toward enhancing and complimenting the results reported herein:

- Dedicated study within each of the six indicators developed is required to fully understand the antecedents as well as the predictors of outcomes on each indicator. While this research has presented an initial exploration into this data, it has given rise to more questions as a result of the demographic and related analysis.
- Race of respondent was known to play a significant role in overall results within this research. However the detailed *interactions* of variables such as income, employment, education and location need to be further investigated toward establishing a path of causality toward developing more effective measurement and intervention strategies.
- The domain of *scientific knowledge*, though broadly defined in this research, may require further investigation to ascertain the areas specifically relevant to the South African population. The selection of 7 science-subject categories and 9 questionnaire items was to ensure as broad coverage as possible, however this may be expanded to include a greater number of items where funding is available to do so.
- An increase in the coverage of attitudinal items to better profile and assist in segmentation activities will become a required part of future assessments of this nature. Further to this, race was found to be the only predictor of outcome on the attitudinal index, which raises additional questions as to how this influences attitudes to science. Related to this was the exceptionally high degree of positive attitudes recorded within the coloured sub-sample, that is not congruent with performance on the other indices – within this aspects an investigation into population dynamics and its role within attitudes to science may be required.
- A key finding of this research was that despite *interest in science*, a large proportion of South Africans do not participate in science engagement activities. This research was not designed to ascertain the reasons for this; however, future research may investigate these reasons to ascertain barriers to attendance at science engagement activities such that science communicators may use this toward better programs and more accessible activities.
- Each of the indices developed may be considered in further analysis as predictors of performance on each of the other indicators. The complexity of this analysis was beyond the scope of this research, however as discussed by Guenther and Weingart (2016) evidence

may exist of complex interactions between these indicators and their relative influence on each other.

- Additional research and development of the *measure of attitudinal ambivalence* as well as the *science-audience segmentation* may broaden the discussion and variety of tool used within this field of research.

12.6 GENERAL CONCLUSION

It is hoped that this research and the resources produced within its results will be of value to researchers, policy makers and science communicators (in both the private and public sector), as South Africa continues its shift toward a knowledge-based economy. As a country on this evolutionary path of changing modes and means of production, it remains essential that the general population of South Africa is knowledgeable and adequately skilled to make an active contribution within this changing economic landscape. Likewise as advances in technology influence work environments, increasingly primary production (agriculture; mining etc.) is reliant on science and technology derived solutions that would not be accessible to a workforce lacking the appropriate skills to meaningfully engage with these rapid changes in the employment context. As South Africa tends toward becoming a continental leader and global role player, the internationalisation of the domestic workforce will require a degree of proficiency with respect to basic understanding of science and technology toward meeting the socio-economic objectives of the country.

Beyond employment, as science and technology become an increasingly more prevalent part of daily life, due to constant innovation, basic services, communication, health care and factors that may influence general quality of life will become increasingly dependent on users being able to interact with such technologies. The role of science in society must be explored and understood toward better facilitating the social, cultural and economic transformation it will eventually give rise to. Government has a significant role to play in furthering our understanding of the South African public understanding of science. However beyond this there similarly remains the need for the public to be actively engaged in science learning and activities that would promote a bi-directional flow of information to best facilitate an interactive space that promotes the ideals of equality and participation.

The value and contribution of the print, broadcast and online based media cannot be over-stated. These are the mediums people most frequently report encountering science information and there needs to be a greater focus on reliable, accurate and accessible information within the public space and private sector operators. This would encourage the public toward enhanced information seeking behaviour and ultimately increase their knowledge base through a process of informal learning. While the role of education is noted within this study, the importance and value of life-long learning regarding science remains an important factor. Edutainment[147] remains a valuable new tool that broadcasters can employ toward fostering greater informal learning opportunities within the South African public.

As language remains a critical factor in teaching and learning technical subjects, a greater focus on developing a scientific vocabulary within the traditional languages needs to be made. While strides have been accomplished within isiZulu, with the creation of a Zulu scientific dictionary, similar initiatives would assist in ensuring that learning is accessible to a wider demographic in a language that is appropriate; rather than exclusively in English.

The results of this research are also aimed at serving the more immediate need of policy makers and science communicators in addressing the crucial gaps in science communication efforts. Further understanding and the development of tools to enhance the study of the public's relationship with science will go a long way toward not only building a more inclusive innovation system, but also address the crucial social, human and democracy building potential that lies in an awareness of this, often complex, interaction between science and the general public**S** (Reddy *et al*, 2009).

The investigation into the South African public understanding of science with respect to its demographic predictors has highlighted the enormous impact that still influences the many South African public**S.** This diversity should not be seen as factor that divides us, but as a foundation on which we build a future the people of this country deserve. This nations' strength has always rested in its diversity and this will, in time, become its greatest asset.

[We] Believe that South Africa belongs to all who live in it, united in our diversity.

Preamble of the constitution of the Republic of South Africa (1996)

[147] Documentaries, educational programming televised in an informal way

References

Agresti, A.; 2007. An Introduction to Categorical Data Analysis. Second edition. Wiley InterScience

Aiwuyor W, 2011. Calculated Optimism: Africa's Booming Youth Population and Demographic Dividends. Accessed online at: http://face2faceafrica.com/article/calculated-optimism-africa-s-booming-youth-population-and-demographic-dividends. Accessed 12 August 2013

Albright, D, 1994. "South Africa and the Affordable Bomb". Atomic Scientists, No. 4, issue 37 (Jul/Aug 1994).

Allum, N; Sturgis, P; Tabourazi, D; 2008. "Science knowledge and attitudes across cultures: a meta-analysis" *Public Understanding of Science, vol. 17, 1: pp. 35-54.*

Aminrad, Z.; Binti, S. Z.; Zakariya, S.; Hadi, a. S.; Sakari, M.; 2013. Relationship Between Awareness, Knowledge and Attitudes Towards Environmental Education Among Secondary School Students in Malaysia. World Applied Sciences Journal 22 (9): 1326-1333, 2013

Anderson, M; Gouasmia, S; Khan, A; Lorenzetti, C, 2009. "Innovation as a Threat". Available online at: http://www.slideshare.net/abakhan/innovation-as-a-threat. Accessed 16 March 2013

APF, OECD, 2008. ICT in Africa: Boosting Economic Growth and Poverty Reduction. (Accessed 14 July 2010) http://www.oecd.org/dataoecd/46/51/40314752.pdf

ARC: Agricultural Research Council, 2011. Website home page: History of Onderstepoort Veterinary Institute. Accessed 2011-07-08. http://www.arc.agric.za/home.asp?pid=2565

Archibugi, D.; 2004. A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo). World Development Vol. 32, No. 4, pp. 629–654

AU-NEPAD (African Union New Partnership for Africa's Development), 2010. *African Innovation Outlook 2010*, AU-NEPAD, Pretoria.

Aubert, J.E and Reiffers, JL; 2003. Knowledge Economies in the Middle East and North Africa: Toward New Development Strategies. World Bank. Available online at: http://www.ecolabs.org/IMG/pdf/MENA4K.pdf. Accessed 6 March 2013

Babbie, E. R; 2007. The Practice of Social Research. 11th edition. Cengage Learning. Available online at https://www.cengagebrain.co.nz/content/9781133794882.pdf.

Bann, C. M.; Schwerin,M.J.; 2004. "Public knowledge and attitudes scale construction: development of short forms". National Science Foundation – RTI International

Barnett, C. and Mahony, N.; 2011. Segmenting Publics. National Co-ordinating Centre for Public Engagement and the Economic and Social Research Council. Available online at: https://www.publicengagement.ac.uk/sites/default/files/publication/segmenting_publics_2_nov_2011.pdf

Barre, R, 2010. Towards socially robust S&T indicators: indicators as debatable devices, enabling collective learning. Research Evaluation (2010) 19(3): 227-231. Available online at http://rev.oxfordjournals.org/content/19/3/227.full.pdf+html

Battrawi, B; Muhtaseb, R; 2013. The Use of Social Networks as a Tool to Increase Interest in Science and Science Literacy: A Case Study of 'Creative Minds' Facebook Page. Conference presentation: "New Perspectives in Science Education" Florence, Italy 14 - 15 March 2013. Available online at: http://conference.pixel-online.net/npse2013/common/download/Paper_pdf/043-SPI08-FP-Battrawi-NPSE2013.pdf. Accessed 22 November 2013.

Bauer, M; Durant, J and Evans, G; 1994. European Public Perceptions Of Science. International Journal of Public Opinion Research 6, 163-186

Bauer, M. and Durant, J.; 1997. "Belief in Astrology: a Social-Psychological Analysis," *Culture and Cosmos: A Journal of the History of Astrology and Cultural Astronomy* 1: 55–72.

Bauer,M , Petkova, K and Boyadjieva, P.; 2000. "Public Knowledge of and Attitudes to Science: Alternative Measures that may end the "Science War"." *Science, Technology & Human Values.* Vol. 25 (1) p 30-51

Bauer, M., Allum, N & Miller, S.; 2007. "What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda." *Public Understanding of Science*, Vol. 16(1): 79-95

Bauer, M.; 2009. The evolution of public understanding of science - discourse and comparative evidence. Science, technology and society, 14 (2): 221-240.

Bauer, M and Falade, B; 2014. Public understanding of Science – The survey Research. Handbook of Public communication of Science and Technology. London School of Economics and political Sciences. London.

Bayaga, A.; 2010. Multinomial logistic regression: usage and application in risk analysis. Journal of Applied Quantitative Methods, Vol 5, No 2, 2010

Beveridge, A.A. & Rudell, F; 1988 "An Evaluation of 'Public Attitudes toward Science and Technology': Science Indicators: the 1985 Report," *Public Opinion Quarterly* 52: 374–85.

Beyleveld, D and Friele, MB; 2003. Chapter 4.4 (page 166-172) "General Attitudes to Science and Technology in Europe". Chapter in book: Embryo Research in Pluralistic Europe. Springer.

BIS, 2011. Public attitudes to Science; 2011. Department for Business, Innovation and Skills / IPSOS MORI Social research Institute.

Bhorat, H; Meyer, J.B; Mlatsheni, C; 2002. "Skilled Labour Migration from Developing Countries: Study on South And Southern Africa" report for the International Labour Office. Accessed 2011-07-08. Available at http://www.ilo.int/public/english/protection/migrant/download/imp/imp52e.pdf

Blankley, W. O; Arnold, R; 2001. *Public Understand of Science in South Africa – aiming for better intervention strategies.* South African Journal of Science, 97, March / April 2001. South Africa

Blankley, W; Booyens, I; 2010. Building a Knowledge Economy in South Africa. South African Journal of Science. Nov / Dec 2010, Vol. 106 Issue 11/12, p15.

Blik, H. and Goldstein, M; 2013. An Introduction to Social Media for Scientists. Public Library of Science – PLOS online Journal, Vol. 11, Issue 4, April 2013. Available online at: http://www.plosbiology.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pbio.1001535&representation=PDF. Accessed 14 November 2013.

BMHRC; 2008. The Bhopal Gas Tragedy. Available online at http://www.bmhrc.org/Bhopal%20Gas%20Tragedy.htm **Accessed 16 July 20104.**

Bora, A; Heiko, H; 2006. "Participatory science governance revisited: normative expectations versus empirical evidence". *Science and Public Policy,* 33(7), 478–488.

Brochu, P; Deussing, M. A.; Houme, K.; Chuy, M.; 2013 . Measuring Up: Canadian Results of the OECD PISA study: The Performance of Canada's Youth in Reading, Mathematics and Science 2012 First Results for Canadians Aged 15. Statistics Canada. Available online at: http://cmec.ca/Publications/Lists/Publications/Attachments/318/PISA2012_CanadianReport_EN_Web.pdf . Accessed 27 March 2014

Burns, T; O'Connor, D and Stockmayer, S. 2003. "Science Communication: a Conceptual Definition." *Public Understanding of Science*. 12, 183-202.

Burns, M.; Audouin, M.; Weaver, A.; 2006. "Advancing sustainability science in South Africa". *South African Journal of Science*. Vol 102, September/October 2006

Burawoy,M; 2007. *Deliberative democracy in a global context: a South African model of higher education?* Lecture presented at Centre for Education Policy Development 26 December 2007.

Bybee, R. W.; 1997. Achieving Scientific Literacy: From Purposes to Practices. Heinemann Publishers.

Byrnes, R.M; 1996. South Africa: A Country Study. Washington: GPO for the Library of Congress. Located online at: http://countrystudies.us/south-africa/20.htm. Accessed 09 July 2013

Castro-Martínez, E.; Jiménez-Sáez, F; Ortega-Colomer, F. J; 2009. Science and technology policies: A tale of political use, misuse and abuse of traditional R&D indicators. Scientometrics, September 2009, Volume 80, Issue 3, pp 827–844

Center for American Progress, 2012. "Retooling to Ensure America Remains No. 1 in the 21st Century" Series on U.S. Science, Innovation, and Economic Competitiveness. Available online at http://www.americanprogress.org/wp-content/uploads/issues/2012/01/pdf/dwwsp_overview.pdf. Accessed 25 July 2013

Chari, R.; Hogan, J.; Murphy, G., 2010. Regulating Lobbying: A Global Comparison. Manchester University Press.

Chen S. & Ravaillon M.; 2004. How have the world's poorest fared since the early 1980's? World Bank Policy Research Working Paper 3341. Washington, D.C.

Chen, F., Shi, Y., Xu, F.; 2009. An analysis of the Public Scientific Literacy study in China. Public Understanding of Science September 2009 vol. 18 no. 5 607-616

CIA; 2012. "The World Fact book: South Africa 2012". Washington, DC: Central Intelligence Agency. Accessed online on 21-04-2013. Available at https://www.cia.gov/library/publications/the-world-factbook/index.html

Cirksena, M.K.; Flora, J.A., 1995. Audience segmentation in worksite health promotion: A procedure using social marketing concepts. Health Education Research (1995) 10 (2):211-224.

Claassen, G. N; 2009. Covering Science: why we don't measure up. *The Media*. Johannesburg. September 2009 30-31

Claassen, G. N; 2010. Why Journalism is failing the Scientific Age. *Rhodes Journalism Review.* July 2010 42-43

Clarke, R.; Thompson, L.; 2011. A majestic start: How the OECD was won. OECD Observer, online magazine of the OECD. Available online at http://www.oecdobserver.org/news/fullstory.php/aid/3492/. Accessed 13 December 2013

Collins English Dictionary – Complete and Unabridged; 2003. Retrieved November 25 2015 from http://www.thefreedictionary.com/informedness

Conradie, E. S.; 2004. The role of key role players in science communication at South African higher education institutions: an exploratory study. University of Pretoria, South Africa (Unpublished PhD thesis)

Coughlan, S; 2013. England's young adults trail world in literacy and maths. BBC News – Education & Family. 9 October 2013. Available online at: http://www.bbc.com/news/education-24433320. Accessed 22 December 2013

Critchley , C, Turney , L.; 2004. "Understanding Australians' Perceptions of Controversial Scientific Research". Australian Journal of Emerging Technologies and Society. Vol. 2, No. 2, 2004, pp: 82-107

Crush, J; Campbell, E; Green, T; Nangulah, S; Simelane, H, 2005. States of Vulnerability: The Future Brain Drain of Talent to South Africa. Southern African Migration Project. Southern African Research Centre Queen's University, Kingston, Canada.

Cummings, M.; 1979. Random Digit Dialing: A Sampling Technique for Telephone Surveys. Public Opinion Quarterly, 1979, issue 43 (2) page 233-244.

CVCE; 2012. Centre Virtuel de la Connaissance sur l'Europe (CVCE): European Commission. Published online at http://www.cvce.eu/obj/european_commission-en-281a3c0c-839a-48fd-b69c-bc2588c780ec.html. Accessed 06 April 2014.

Daamen, D.D.L. and van der Lans, I.A; 1995 "The Changeability of Public Opinions about New Technology: Assimilation Effects in Attitude Surveys," in M. Bauer (ed.) *Resistance to New Technology*, pp. 81–96. Cambridge: Cambridge University Press.

Dahlman, C. J.; Aubert, J.; 2001. China and the Knowledge Economy: Seizing the 21st Century. WBI Development Studies. *World Bank Publications*

Darzentas, N; Goldovsky, L; Ouzounis, C; Karapiperis, K; Karapiperis, C; 2007. "Science communication media for scientists and the public". EMBO reports VOL 8 NO 10 2007. Accessed online at: http://www.nature.com/embor/journal/v8/n10/full/7401074.html

DeBoer, G. E; 2000. "Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform". *Journal of Research in Science Teaching* vol. 37, no. 6.

Dell, S; 2009. Fifteen years after Apartheid Died. Newspaper article: The Witness (26 Jun 2009) accessed online (12-06-2011): http://www.witness.co.za/index.php?showcontent&global%5B_id%5D=24611

Department of Arts, Culture, Science and Technology (DACST); 1996. *White Paper on Science and Technology*. Pretoria: Government Press.

De Lanerolle, L.; 2012. The New Wave: Who connects to the internet, how they connect and what they do when they connect. *South African Network Society Project. University of Witwatersrand. Available online at:* http://www.networksociety.co.za/internet-report.php

De Sousa W. H; de Souza B; Zamudio Igam, M. P; 2009. "R&D Management and the Stokes Diagram: An exploratory Study". *Journal of Technology Management and Innovation.* Volume 4, Issue 4

Department of Communications; 2011. Department of Communications strategic plan 2011 -2014. Department of Communications, Republic of South Africa. Accessed, 17 May 2011, from, http://www.doc.gov.za/index.php?option=com_docman&task=cat_view&gid=119&Itemid=543 .

Department of Science and Technology (DST); 2007. Innovation towards a knowledge-based economy ten-year plan for South Africa (2008 – 2018). Department of Science and Technology, South Africa. Government Press

Department of Science and Technology (DST); 2008. Ten Year Innovation Plan. Pretoria: Government Press

Department of Science and Technology (DST); 2011. Enhancing the National System of Innovation to support growth and development: A strategy to increase R&D investment in South Africa. Pretoria: Government Press

Department of Science and Technology (DST); 2014. Science Engagement Framework: *Science engaging with society to foster an informed environment for innovation, economic strength and social improvement*. Pretoria: Government Press

Dewey, J.; 1916. DEMOCRACY AND EDUCATION. Macmillan. Accessed online via the "The Project Gutenberg EBook of Democracy and Education, by John Dewey". Available at http://www.gutenberg.org/files/852/852-h/852-h.htm. Accessed: 19 November 2013

Diseko, L; 2010. "South Africa's brain-drain generation returning home". CNN online edition: http://articles.cnn.com/2010-11-18/world/south.africa.migration_1_south-africans-violent-crime-job-seekers?_s=PM:WORLD

Dolnicar, S. & Rossiter, J. R.; 2009. "Not offering don't know options in brand image surveys contaminates data". Australia and New Zealand Marketing Academy (ANZMAC) Conference (pp. 1-7). Melbourne, Australia: Australian & New Zealand Marketing Academy. Available online AT: http://ro.uow.edu.au/cgi/viewcontent.cgi?article=3554&context=commpapers

Drubin, D., G.; Kellogg, D. R.; 2012. English as the universal language of science: opportunities and challenges. Molecular Biology of the Cell vol. 23 no. 8

Dunn, L. A.; 2013. "Teaching in higher education: can social media enhance the learning experience?" Interdisciplinary Science Education, Technologies and Learning. The University of Glasgow. Available online at: http://www.gla.ac.uk/media/media_276225_en.pdf

Du Plessis, H, 2011. "Science and Society: Public Understanding of Science (PUS) in South Africa and other collaborations". Unpublished: HSRC Seminar series presentation. 25 January 2011. Pretoria

Durant, J. R; Evans, G. A; Thomas, G. P; 1989. The public understanding of science. Nature 340, 11-14

Durant, J. 1999. "Participatory Technology Assessment and the Democratic Model of the Public Understanding of Science." *Science and Public Policy*. 26(5): 313-319

Eagly, A.H. and Chaiken, S ; 1993 *The Psychology of Attitudes*. Fort Worth: Harcourt Brace College Publishers.

Eden, G; 2014. REVIEW: Special Eurobarometer 401: Survey Summary on Responsible Research and Innovation, Science and Technology coordinated by the European Commission. Journal of Responsible Innovation, January 2014. Available online at: http://users.ox.ac.uk/~lina1361/Eden-JRRI-Review.pdf. Accessed 09 April 2014.

Edgerton, D; 1996. The 'White Heat' Revisited: The British Government and Technology in the 1960s. Twentieth Century British History, Vol. 7, No. 1, 1996, pp. 53-82. Available online at: https://workspace.imperial.ac.uk/humanities/Public/files/Edgerton%20Files/edgerton_white_heat.pdf. Accessed 16 October 2013.

Edgerton, D; 2004. 'The linear model' did not exist: Reflections on the history and historiography of science and research in industry in the twentieth century". In Grandin, K and Wormbs, N (eds), The Science–Industry Nexus: History, Policy, Implications. (New York: Watson, 2004). Available online at https://workspace.imperial.ac.uk/historyofscience/Public/files/edgerton_linear_model_did_not_exist.pdf

Egbetokun, A; Siyanbola, W; Olamade, O; Adeniyi, A; Irefin, I; 2008. "Innovation in Nigerian SMEs: types and impact," MPRA Paper 25338, University Library of Munich, Germany, revised 2008.

Eisner, P; 2009. Measuring South Africa's progress since apartheid. World Focus online edition. Accessed 12-06-2011 from: http://worldfocus.org/blog/2009/04/27/measuring-south-africas-progress-since-apartheid/5134/

Einsiedel, F, Jelsøe, E., Breck, T; 2001. "Publics at the technology table: the consensus conference in Denmark, Canada, and Australia". *Public Understanding of Science vol* 10 (2001) 83–98

Elkana, Y.; Lederberg, J.; Merton, R. K.; Thackray, A.; Zuckerman, H; 1978. "Toward a metric of science. The Advent of Science Indicators". Based upon a conference sponsored by the Center for Advanced Study in the Behavioral Sciences and the Social Science Research Council."

Ellis, F. R. G; 2001. "Science research policy in South Africa". Royal Society of South Africa.

European Commission; 2001. Eurobarometer 55.2: Europeans, science and technology. European Commission, Directorate-General for Press and Communication, Public Opinion Sector. Report available online at: http://ec.europa.eu/research/press/2001/pr0612en-report.pdf. Accessed 08 April 2014.

European Commission; 2013a. Special Eurobarometer 401 Responsible Research and Innovation (RRI), Science and Technology report. Available online at http://ec.europa.eu/public_opinion/index_en.htm. Accessed 08 April 2014

European Commission, 2013b. Welcome, Croatia! Press release on European Commission website. Available online at http://ec.europa.eu/news/eu_explained/130701_en.htm. Accessed 08 April 2014

Evans, G; Durant, D; 1995. The relationship between knowledge and attitudes in the public understanding of science in Britain. Public Understanding of Science January 1995 vol. 4 no. 1 57-74

Everitt, B.S.; 2002. The Cambridge Dictionary of Statistics, 2nd Edition.

Falk, J. H.; Storksdieck, M.; Dierking, L. D; 2007. Investigating public science interest and understanding: evidence for the importance of free-choice learning. Public Understand of Science, vol. 16 no. 4 pp 455-469

Fedderk, J; 2001. "Technology, Human Capital and Growth: Evidence from a Middle Income Country Case Study Applying Dynamic Heterogeneous Panel Analysis". ERSA, University of the Witwatersrand. Accessible online at http://www.tips.org.za/files/

Feller, I & Gamota, G; 2007. Science indicators as reliable evidence. Minerva (2007) 45:17

Felt, U., & Fochler, M.; 2008. "The Bottom-up meanings of the Concept of Public Participation in Science and Technology." *Science and Public Policy.* 35 (7) p489-499.

Feinstein, N.; 2011. Salvaging science literacy. Science Education. Volume 95, Issue 1, pages 168–185, January 2011.

Field, A.; 2005. Discovering Statistics Using SPSS. 2nd ed. London: Sage

Foundation for Research Development (FRD), 1996. "South African Science and Technology Indicators". Chapter 6: Public Understand of Science and Technology. Pretoria, South Africa

Fourie, J; 2006. *The South African poor white problem in the early 20th century: Lessons for poverty today.* Bureau for Economic Research & University of Stellenbosch (Department of Economics).

Fuller, S; 2000. Book Review: Increasing Science's Governability: Response to Hans Radder. *Science Technology Human Values,* 2000, Vol. 25: No. 4, pp 527-534

Freeman, C. and Soete, L.; 2007. Developing science, technology and innovation indicators: what we can learn from the past. UNU-MERIT Working Paper Series. January 2007. ISSN 1871-9872

Gardner, P.; 1975. Attitudes to science. Studies in Science Education, 2, 1–41.

Gardner, P.; 1995. Measuring attitudes to science. Research in Science Education, 25, 283–289.

Gascoigne, T. H. and Metcalse, J. E.; 1994. Public Communication of Science and Technology in Australia. Published in *When Science Becomes Culture*, proceedings from a conference held in Montreal, Canada April 10-13 1994. Available online at: http://www.cirst.uqam.ca/pcst3/PDF/actes/When%20science%20becomes%20culture.pdf. Accessed 06 February 2014

Gastrow, M; 2010. The Public Understanding of Biotechnology in the Media. A report for the National Advisory Council on Innovation and the National Biotechnology Advisory Committee. Education and Skills Development Research Programme Human Sciences Research Council

Gauchat, G; 2010. The cultural authority of science: Public trust and acceptance of organized science. Public Understanding of Science, Vol 20, 2010.

Gault, F; 2011. “Social impacts of the development of science, technology and innovation indicators”. UNU-MERIT. United Nations University – Maastricht Economic and social Research and training centre on Innovation and Technology. Available online at: www.merit.unu.edu/.../wppdf/.../wp2011-008

Gedye, L; 2012. “African mobile markets on exponential growth track” Mail and Guardian November 23 to 29 2012, page 5.

Godin, B.; 2001. The emergence of S&T indicators: why did governments supplement statistics with indicators. Paper No. 8. Montreal.

Godin, B.; 2000. Outline for a history of science measurement. Paper No. 1. Montreal.

Godin, B.; 2005. Measurement and Statistics in Science and Technology: 1920 to the Present. London, Routledge.

Godin, B.; 2010. Taking Statistics (More) Seriously: The Measurement of Science, Technology and Innovation and its Future. Prepared for a UNESCO Workshop on “New Dimensions of STI Indicators”, Paris, 9-10 December 2010.

Godin, B; Gingras, Y.; 2000. “What is scientific and technological culture and how is it measured? A multidimensional model”. *Public Understanding of Science* 2000 9: 43

Goedhuys, M, 2007. The impact of innovation activities on productivity and firm growth: evidence from Brazil. United Nations University, Maastricht Economic and social Research and training center on Innovation and Technology in its series UNU-MERIT Working Paper Series with number 002.

Goolam, F.; 2001. The scientific and technological literacy of first year students: the effect of traditional school curriculum. Unpublished PhD thesis. University of Pretoria. Available online at http://upetd.up.ac.za/thesis/submitted/etd-12092005-155023/unrestricted/00front.pdf. Accessed 23 October 2013.

Gorsuch, R. (1969). Beliefs, attitudes and values, by Milton Rokeach – review. American Sociological Review, Vol. 34, No. 2, 267-268

Gregory, J; 2001. Public understanding of science: lessons from the UK experience. Available online at: http://www.scidev.net/global/communication/feature/public-understanding-of-science-lessons-from-the.html. Accessed 15-11-2013

Gregory, J., & Lock, S.; 2008. "Evolution of "Public Understanding of Science": Public engagement as a Tool of Science Policy in the UK." *Sociology Compass.* 2 (4): 1252-1265.

Gruber, J. and Caffrey, M; 2005. HIV/AIDS and community conflict in Nigeria: implications and challenges. Social Science & Medicine 60 (2005) 1209–1218

Grupp, H.; Mogee, M. E.; 2004. Indicators for national science and technology policy: how robust are composite indicators? Research Policy, vol. 33 page 1373–1384

Guenther L, Weingart P.; 2106. A unique fingerprint? Factors influencing attitudes towards science and technology in South Africa. South African Journal of Science. 112. Available online at: http://sajs.co.za/unique-fingerprint-factors-influencing-attitudes-towards-science-and-technology-south-africa/lars-guenther-peter-weingart

Harrison, R. ; Kessels, J; 2003. “Human Resource Development in a Knowledge Economy”. CIPD Publishers

Hasan, R.; 2013. “First world problems: why economic development categories need a rethink”. Article published in the Guardian Online. Available online at http://www.theguardian.com/business/economics-blog/2013/nov/22/first-world-problems-economic-development-categories. Accessed 25 January 2014.

Hattie, J.; 1985. Methodology Review: Assessing Unidimensionality of Tests and items. Applied Psychological Measurement, vol 9, No 2, June 1985.

Hawken, A. and Munck, G.L.; 2013.Cross-National Indices with Gender-Differentiated Data: What Do They Measure? How Valid Are They? Social Indicators Research May 2013, Volume 111, Issue 3, pp 801–838

Hays, A. R; 2001. The Role of Interest Groups. Extracts from his book: Who Speaks for the Poor? Routledge. Extract available online at: http://www.ait.org.tw/infousa/zhtw/docs/demopaper/dmpaper9.html. Accessed 05 February 2014

Hazen, R. M., and J. S. Trefil; 2009. Science Matters: Achieving Scientific Literacy. Anchor House Publishing. New York.

HEMIS-DoE, 2009. By special data sharing policy with HSRC.

Henseler, J.; Ringle, C. M.; Sarstedt, M.; 2015. A new criterion for assessing discriminant validity in variance-based structural equation modelling. The Journal of the Academy of Marketing Science (*JAMS*) (2015) 43:115–135

Hock, D. K. W.; 2007. Legacies of World War II in South and East Asia. Institute of Southeast Asian Studies, Singapore. p. 48. Available online at http://www.google.co.za/books?id=awLp4TeUkzoC&printsec=frontcover&redir_esc=y#v=onepage&q&f=false. Accessed 18 March 2014.

Hodson, D.; 2008 Towards Scientific Literacy. A teacher's guide to the History, Philosophy and Sociology of Science. Rotterdam: Sense Publishers

Hodson, D.; 2009. Toward scientific literacy: A teachers' guide to the history, philosophy and sociology of science. Sense Publishers. The Netherlands. Available online: https://www.sensepublishers.com/media/1191-towards-scientific-literacy.pdf . Accessed 02 January 2014.

Holbrook, J.; Rannikmae, M.; 2009. The Meaning of Scientific Literacy. International Journal of Environmental & Science Education: special issue on scientific literacy. Vol. 4, No. 3, July 2009, 275-288. Available online at: http://www.ijese.com/IJESE_v4n3_Special_Issue_Holbrook.pdf. Accessed 03 October 2013.

House of Lords Report, 2000. Science and Society. Her Majesty's Stationery office. London. Available online at: http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm

Howitt, P; 2007. "Innovation, Competition and Growth". *C.D. Howe Institute Commentary*. No. 246, April 2007

Hrbek, Ivan; Fasi, Muhammad; 1988. Africa from the Seventh to the Eleventh Century. London: UNESCO.

HSRC. 2004. Report on Public Understanding of Biotechnology. Available online at www.hsrc.ac.za

HSRC, 2011. Trends in International Mathematics and Science Study (TIMSS). International Association for The Evaluation Of Educational Achievement (IEA).

HSRC-CeSTII, 2012. "Results of the National Research and Experimental Development Survey 2009-2010". Research commissioned by the Department of Science and Technology. Pretoria, South Africa

Hu, M. and Peng, Y.; 2010. Chinese lacking scientific literacy. News article in China Daily published 2010-11-02. Available online at: http://www.chinadaily.com.cn/china/2010-11/02/content_11487848.htm. Accessed 18 June 2014.

Hurd, P. 1958. Science literacy: It's meaning for American schools. Educational Leadership, 16, 13 – 16, 52.

Hurd, P. 1998. Scientific literacy: New minds for a changing world. Science Education 82: 407—416.

Hurley, H. M.; 1998. Science Literacy: Lessons from the First Generation. University at Albany, State University of New York. Research Matters No. 9801, March, 1998

Hwang, K.; 2005. The Inferior Science and the Dominant Use of English in Knowledge Production: A Case Study of Korean Science and Technology. Science Communication June 2005 vol. 26 no. 4 390-427

IEA-TIMSS, 2007. Trends in International Mathematics and Science Study (TIMSS) 2007. Available online: http://nces.ed.gov/timss/results07.asp

Ighobor, K; 2013. Africa's youth: a "ticking time bomb" or an opportunity? Africa Renewal. Accessed online at: http://www.un.org/africarenewal/magazine/may-2013/africas-youth-ticking-time-bomb-or-opportunity. Accessed 12 August 2013

IMF, 2013. Report for Selected Countries and Subjects: South Africa 2012. Database available online at: http://www.imf.org/external/pubs. Accessed April 2013.

Indiwe, 2012. South African Airways inflight magazine article. Issue: February 2012. Page 43. Editor Piet Van Niekerk.

Ishii, M. 2002. Public Understanding of Science and Technology in Japan 'The influence of people's liking of science at school age on their understanding of science after grown-up. National Institute of Science and Technology Policy. Available online at: http://www.saasta.ac.za/scicom/pcst7/masamichi.pdf. Accessed 24 January 2014.

Jasanoff, S; 1997. "Civilization and madness: the great BSE scare of 1996". Public Understanding of Science July 1997 vol. 6 no. 3 221-232

Kahn, M. J., Blankley W.O.; 2005. *The history of research and experimental development measurement in South Africa and some current perspectives*. South African Journal of Science, 101 March 2005.

Kaplan, D; 2008a." Science and Technology Policy in South Africa : Past Performance and Proposals for the Future". In *Science Technology Society* 2008 13: 95

Kaplan, D; 2008b. "Science and technology policy in South Africa: a critical assessment of past performance and of proposed future directions". Conference Paper, Oxford 2008.

Kawamoto, S.; Nakayama, M.; Saijo, M.; 2013. A survey of scientific literacy to provide a foundation for designing science communication in Japan. Public Understanding of Science. August 2013 vol. 22 no. 6 674-690

Kennedy, P; 1989. The Rise and Fall of the Great Powers- Economic change and Military conflict from 1500 to 2000. Fontana Press, London, 1989.

Kennett, K, 2005. *South Africa: Tackling the legacy of apartheid.* Thomson Learning. Accessed online (12-06-2011) http://www.swlearning.com/economics/kennett/kennett2e/Kennett_SouthAfrica.pdf

Khumalo, S; 2013. School with zero pass rate an omen of crisis. Independent Online Newspapers. Available online at http://www.iol.co.za/news/south-africa/limpopo/school-with-zero-pass-rate-an-omen-of-crisis-1.1548020#.Ueba640-uOF. Accessed July 17 2013 at 09:59am

King, C, 2010. South African Science: Signs of Progress. Science Watch. Available online at http://archive.sciencewatch.com/ana/fea/10mayjunFea/. Accessed 14 July 2012

Knighton, T.; Brochu, P; Gluszynski, T.; 2010. Measuring Up: Canadian Results of the OECD PISA study: The Performance of Canada's Youth in Reading, Mathematics and Science 2009 First Results for Canadians Aged 15. Statistics Canada. Available online at: http://www.statcan.gc.ca/pub/81-590-x/81-590-x2010001-eng.pdf. Accessed 08 January 2014

Kraak, A., & Press, K.; 2008. *Human Resources Development Review 2008: Education, Employment and Skills in South Africa*. HSRC Press: Cape Town.

Lamberts, R; Grant, W. J; Martin, A.; 2010. Public opinion about science. ANUPoll: The Australian National University. ANU College of Physical and Mathematical Sciences and ANU College of Arts and Social Sciences.

Laugksch, RC. 1996. *Development of a Test for Scientific Literacy.* Cape Town: UCT (Unpublished PhD thesis)

Laugksch, RC and Spargo, P.E.; 1999. *Scientific Literacy of selected South African matriculants entering tertiary education: a baseline survey.* South African Journal of Science. Vol 95 pp 427-432. October 1999.

Laugksch, RC. 2000 "Scientific Literacy: A Conceptual Overview." *Science Education*. 84(1), 71-94.

Layton, D., Jenkins, E., Donnelly, J.; 1994. Scientific and Technological Literacy: Meanings and Rationales - An Annotated Bibliography. Centre for Studies in Science and Mathematics Education, University of Leeds. UNESCO. Available online at: http://www.unesco.org/education/pdf/325_94.pdf. Accessed 8 December 2013

Lee, O.; 2001. Culture and Language in Science Education: What Do We Know and What Do We Need to Know? Journal of Research in Science Teaching vol. 38, no. 5, pp. 499 – 501.

Lewenstein, B. V.; 1992. The meaning of 'public understanding of science' in the United States after World War II. Public Understanding of Science January 1992 vol. 1 no. 1 45-68

Liu, X; 2009. Beyond Science Literacy: Science and the Public. International Journal of Environmental & Science Education Vol. 4, No. 3, July 2009, 301-311

Lizotte, M. K; Sidman, A.H.; 2009. Explaining the Gender Gap in Political Knowledge. Politics & Gender, 5 (2009), 127 –151. Printed in the U.S.A. available online at: http://web.pdx.edu/~mev/pdf/PS471_Readings_2012/Lizotte_Sidman.pdf

Locke, S; 2002. "The Public Understanding of Science-A Rhetorical Invention. *Science Technology Human Values* 2002 27: 87

Lodge, J; 2012. Education in the information age: is technology making us stupid? *The Conversation*. Available online at http://theconversation.com/education-in-the-information-age-is-technology-making-us-stupid-10844. Accessed 06 May 2013

Long, J. S., Freese, J.; 2001. Regression models for categorical dependent variables using STATA. A Stata Press Publication. Available online at: http://investigadores.cide.edu/aparicio/data/refs/Long%26Freese_RegModelsUsingStata_2001.pdf

Maierbrugger, A, 2013. Malaysia bans opening of new universities. Article in the Www.investvine.com/ news portal. Available online at: http://investvine.com/malaysia-freezes-setting-up-of-universities/. Accessed 10 July 2014.

Malaysian Biotechnology Information Centre (MABIC), 2014. Strategies for biotech in Malaysia. Malaysian Biotechnology Information Centre website. Online link: http://www.bic.org.my/biotech-in-malaysia/strategies. Accessed 16 June 2014.

Malaysian Science and Technology Information Centre (MASTIC), 1998. *Public Awareness of Science and Technology Malaysia 1998.* Available online at: http://www.mastic.gov.my/documents/10156/919963c4-b14c-4368-b7df-9b96dfe94eaf. Accessed 12 July 2014.

Malaysian Science and Technology Information Centre (MASTIC), 2008. *Public Awareness of Science and Technology Malaysia 1998.* Available online at: http://www.mastic.gov.my/documents/10156/050c1993-dd1f-485b-b92b-903736afda55. Accessed 12 July 2014.

Mansour, N; 2009. "Science-Technology- Society (STS): A new paradigm in Science Education". Bulletin of Science, Technology and Society. 29(4), 287-297. Available online at: https://ore.exeter.ac.uk/repository/bitstream/handle/10871/11347/a%20new%20paradigm.pdf?sequence=2 . Accessed 27 January 2014.

Marais, H.C and Pienaar, M; 2010. "Evolution of the South African Science, Technology and Innovation system 1994-2010: an Exploration". *African Journal of Science, Technology, Innovation and Development.* Volume 2 Number 3, 2010. Page 82-109

McCarthy. M; 2010. "Public opinion stopped GM, says campaigner". *The Independent* . Published 26-09-2010. Available online at : http://www.independent.co.uk/environment/green-living/public-opinion-stopped-gm-says-campaigner-2089974.html

McCurdy, R. 1958. Toward a population literate in science. The Science Teacher, 25, 366 - 368, 408.

McGregor, D. and Kearton, G.; 2010. What do researchers say about scientific literacy in schools? Article in the Association for Science Education (ASE) journal: Education in Science. November 2010 (240)

Millar, R.; 2007. 'Twenty-first Century Science: Insights from the design and implementation of a scientific literacy approach in school science', International Journal of Science Education, 28, (13), 1499–1522

Miller, J.D. 1983 "Scientific Literacy: a Conceptual and Empirical Review," *Daedalus* Spring: 29–48.

Miller, J.D. 1987 "Scientific Literacy in the United States," in *Communicating Science to the Public*, pp. 19–40. Chichester: Wiley.

Miller, J.D. 1992 "Towards a Scientific Understanding of the Public Understanding of Science and Technology," *Public Understanding of Science* 1: 23–30.

Miller, J.D.; 1996. Scientific literacy for effective citizenship. State University of New York Press, Albany, NY

Miller, J.D. 1998. "The Measurement of Civil Scientific Literacy." *Public Understanding of Science.* Vol 7 pp 203-223

Miller, J. D.; 2004. "Public Understanding of, and Attitudes toward, Scientific Research: What We Know and What We Need to Know." *Public Understanding of Science.* 13: 273-294.

Miller, S. 2001 "Public Understanding at the Crossroads," *Public Understanding of Science* 10: 115–20.

Miller, S., Caro, P., Koulaidis, V., de Semir, V., Staveloz, W. and Vargas, R. (2002) *Benchmarking the Promotion of RTD Culture and Public Understanding of Science*. Brussels: Commission of the European Communities.

Ministry of Science, Technology and Innovation (MOSTI) – Malaysia, 2014. *Introduction and Background.* Ministry of Science, Technology and Innovation official website. Located at http://www.mosti.gov.my/. Last updated: 25 June 2014. Accessed 25 June 2014.

Moon Hee, K.; 2005. "*Human Resources Development for Knowledge Economy - Republic of Korea".* Asian Development Bank Institute.

Motshekga, A. 2011. "2010 Matric pass rate 67.8%". News article on news 24 website (accessed 02-03-2011) http://www.news24.com/SouthAfrica/News/2010-matric-pass-rate-678-20110106

Mouton, J; Waast, R; Boschof, S. C; Grebe, E; Ravat, E; Ravjee, N; 2001. "Country Report on South Africa", in *Science in Africa at the dawn of the 21st century*. University of Stellenbosch (South Africa) and IRD (Paris)

Mouton, J ; Geevers, W, 2009. "Introduction: Genesis and history of public science in South Africa", in *The State of Science in South Africa*, 2009. Published by Academy of Science of South Africa (ASSAF). South Africa

Mouton, J; Boshoff, N; 2010. *Bibliometric Analysis of Scientific Output of Selected African Countries.* Chapter in African Innovation Outlook, 2010. African Union-Nepad-SEDA Publication

MRC, 2001. *Thirty years of the MRC - a history*. Medical Research Council of South Africa Website. Located at http://www.mrc.ac.za/history/history.pdf. Accessed 09 July 2013.

Murray, J. F, 1963. "History of the South African Institute for Medical Research, *South African Medical Journal*. April 1963

Nagahama, H, 1994. Scientific Literacy in Japan. Historical and Cultural Permeation and Current Changes. Published in *When Science Becomes Culture*, proceedings from a conference held in Montreal, Canada April 10-13 1994. Available online at: http://www.cirst.uqam.ca/pcst3/PDF/actes/When%20science%20becomes%20culture.pdf. Accessed 06 February 2014

NASA, 2013. "The Decision to Go to the Moon: President John F. Kennedy's May 25, 1961 Speech before a Joint Session of Congress". National Aeronautics and Space Administration - NASA History Office. Available online at http://history.nasa.gov/moondec.html. Updated October 29, 2013. Accessed 20 November 2013.

National Council of Applied Economic Research (NCAER). 2005. *India Science Report*. National Council of Applied Economic Research: New Deli.

National Planning Commission (South Africa), 2012. National Development Plan 2030 Our Future-make it work. Department of the Presidency. Government Press. ISBN: 978-0-621-41180-5

NBEET, 1993. What do they know? : The understanding of science and technology by children in their last year of primary school in Australia. Commissioned report by the Australian National Board of Employment, Education and Training no. 23. Canberra: Australian Government. Publication Services, 1993.

Ndulu B. J; 2004. "Human Capital Flight: Stratification, Globalization, and the Challenges to Tertiary Education in Africa". *Journal of Higher Education in Africa* Vol. 2, No. 1, , pp. 57–91

NEPAD*. 2006. Africa's Science & Technology Consolidated Plan of Action.* Compiled Dr John Mugabe and Prof Aggrey Ambali. Available at: http://www.nepadst.org/doclibrary/pdfs/doc27_082005.pdf

Nisbet, M. C.; Scheufele, D. A.; Shanahan, J.; Moy, P.; Brossard, D.; Lewenstein, B. V.; 2002. "Knowledge, Reservations, or Promise? A Media Effects Model for Public Perceptions of Science and Technology". Communication Research. 29(5):584-608

NISTEP, 2002. The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan. National Institute of Science and Technology Policy Ministry of Education, Culture, Sports, Science and Technology. Available online at: http://www.nistep.go.jp/achiev/sum/eng/rep072e/rep72se.pdf. Accessed 24 January 2014

Noble, M., Barnes, H., Wright, G., Roberts, B.; 2008. Small Area Indices of Multiple Deprivation for South Africa. Prepared for the UNU-WIDER Conference. Available online at www.hsrc.ac.za/en/research-data/ktree-doc/1160

Noble, D; 2013. "We are still saving British science from Margaret Thatcher?" Nature Online. April 17, 2013. Available online at http://www.nature.com/news/we-are-still-saving-british-science-from-margaret-thatcher-1.12800. Accessed 06 May 2013

NORC, 2013. General social surveys, 1972-2012 cumulative codebooks. Available online at: http://publicdata.norc.org/GSS/DOCUMENTS/BOOK/GSS_Codebook_intro.pdf. Accessed 25 March 2014

Norris, S. P & Phillips, L. M.; 2003. How Literacy in Its Fundamental Sense Is Central to Scientific Literacy. Science Education, Volume 87, Issue 2, pages 224–240, March 2003

Nowotny, H, P Scott and M Gibbons 2001. *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*, Cambridge, UK: Polity Press.

NPTEL, 2013. Humanities and Social Sciences – Science, Technology and Society Lecture 27: Influence of Freedom *Movements on Scientific Research in India*. Available online at http://nptel.ac.in/courses/109103024/pdf/module5/SM%20Lec%2027.pdf. Accessed 05 July 2014

NRUHSE, 2011. Russian Monitoring Survey of Innovative Behaviour of the Population by the National Research University Higher School of Economics. Available online at: http://www.hse.ru/en/monitoring/innpeople/inp1#03

NSF, 2010. *Science and Engineering Indicators 2010*. Arlington, United States of America

NSF, 2014. National Science foundation: *Science and Engineering Indicators 2014*. Available online at http://www.nsf.gov/statistics/seind14/. Accessed 25 March 2014.

OECD, 1976. *Science and Technology Indicators*. Available online at: http://www.oecd.org/science/inno/msti.htm

OECD, 1996. "The Knowledge-Based Economy" Organisation for Economic Cooperation and Development. Paris

OECD; 2006. Assessing Scientific, Reading and Mathematical Literacy: *A Framework for PISA 2006*. Available online at: http://www.keepeek.com/Digital-Asset-Management/oecd/education/assessing-scientific-reading-and-mathematical-literacy_9789264026407-en#page22. Accessed 27 March 2014.

OECD, 2007. Organisation for Economic Co-operation and Development: '*Review of South Africa's Innovation policy*', Paris: Directorate for Scientific and Technology Policy OECD. 26-27 March.

OECD, 2009. Assessment framework: key competencies in reading, mathematics and science. Available online at: http://www.oecd.org/pisa/pisaproducts/44455820.pdf. Accessed 27 March 2014

OECD, 2010. *Main Science and Technology Indicators.* 2009/01 Edition available online at: www.oecd.org/sti/msti

OECD, 2014. PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014), PISA, OECD Publishing. Available online at http://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-I.pdf. Accessed February 2014

Office of Science and Technology & The Welcome Trust; 2000. Science and the Public A Review of Science Communication and Public Attitudes to Science in Britain. Available online at http://tinyurl.com/6a5b22e. Accessed 22 January 2014.

Osborne, J; 2003. Attitudes towards science: a review of the literature and its implications. International Journal of Science Education. Vol. 25, No. 9, 1049–1079. Available online at: https://cset.stanford.edu/sites/default/files/files/documents/publications/Osborne-Attitudes%20Toward%20Science.pdf

Osborne, J.; 2007. 'Science education for the Twenty First Century', Eurasia Journal of Mathematics, Science and Technology Education, 3, (3), 173–184

Osborne, A; 2013. "Margaret Thatcher: one policy that led to more than 50 companies being sold or privatised". In the Telegraph. Located online at: http://www.telegraph.co.uk/finance/comment/alistair-osborne/9980292/Margaret-Thatcher-one-policy-that-led-to-more-than-50-companies-being-sold-or-privatised.html. Accessed 04 September 2014

Ostrom, T.M.; 1969. The relationship between the affective, behavioral, and cognitive components of attitude. Journal of Experimental Social Psychology, Volume 5, Issue 1, January 1969, Pages 12–30

Otsubo, S. T; 2007. Post--war Development of the Japanese Economy. Presentation Available online at http://www.gsid.nagoya-u.ac.jp/sotsubo/Postwar. Accessed 10 February 2014.

Pagano, U; Ross, M.A.; 2009. "The crash of the knowledge economy" Cambridge Journal of Economics (2009) 33 (4): 665-683.

Pardo, R and Calvo, F; 2002. Attitudes toward science among the European public: a methodological analysis. Public Understand. Science 11 (2002) page 155–195.

Pella, M. O.; O'hearn, G. T.; Gale, C. W.; 1966. Referents to scientific literacy. Journal of Research in Science Teaching. Volume 4, Issue 3, pages 199–208, September 1966

Perkins, P; Fedderke, J; Luiz, J, 2005. An analysis of economic infrastructure investment in South Africa. CSSR Working Paper No. 102. Centre for Social Science Research. University of Cape Town

Petraglia, M. D., Allchin, B; 2007. "Human evolution and culture change in the Indian subcontinent", in *The Evolution and History of Human Populations in South Asia: Inter-disciplinary Studies in Archaeology, Biological Anthropology, Linguistics and Genetics*, Springer.

Pianta, M, 2004. "The impact of innovation on jobs, skills and wages". Economia e Lavoro, n.1, 2004

Piedmont, R., L.; 2014. "Inter-item Correlations". Encyclopaedia of Quality of Life and Well-Being Research. Pages 3 303 - 3 304.

Pike, J, 2010. "Nuclear Weapons Program – South Africa". Globalsecurity.org. Retrieved 15 June 2011.

Polzer, T; 2010. Migration Fact Sheet 1: Population Movements in and to South Africa. Forced Migration Studies Programme. University of the Witwatersrand. Available online at: http://www.cormsa.org.za/wp-content/uploads/2010/07/fmsp-fact-sheet-migration-in-sa-june-2010doc.pdf . Accessed 17 May 2013

Pouris, A; 1989. The hidden crisis - S&T and Manpower development in South Africa. Pretoria, South Africa: Foundation for Research and Development

Pouris, A. 1991. Understanding and appreciation of science by the public in South Africa. South African Journal of Science. Vol 87, August 1991.

Pouris, A. 1993. Understanding and appreciation of science among South African teenagers. South African Journal of Science. Vol 89, February 1993.

Pouris, A. 2001. Interests, Public attitudes and Sources of Scientific Information in South Africa.

Pouris, A. 2006. "Assessing the knowledge base for biotechnology in South Africa." *Scientometrics* 68(1): 97-108.

Power, D; 1897. "Sharp, William (1805-1896)". Dictionary of National Biography, 1885-1900, Volume 51. Smith, Elder & Co. Accessed on 22 October 2013. Available online at:

http://en.wikisource.org/wiki/Sharp,_William_(1805-1896).

Pronina, L; 2013. China to Influence Emerging Economies More Than U.S. Bloomberg News service. Accessed 06 June 2014. Available online at http://www.bloomberg.com/news/2013-01-10/china-to-influence-emerging-economies-more-than-u-s-hsbc-says.html.

Pwiti, G.; 1991. "Trade and economies in Southern Africa: the archaeological evidence". *Zambezia* XVIII (18) 2

Raza, G., Singh, S., Dutt, B.; 1995. Public Understanding of Science and Literacy Campaign in India. National Institute of Science, Technology and Development Studies (CSIR). Available online at: http://st.niscair.res.in/sites/default/files/MHRD%201995%20report.pdf. Accessed 15 July 2014.

Raza, G., Singh, S., & Dutt, B. 2002. "Public, Science, and Cultural Distance." *Science Communication.* 23(3):293-309

Raza, G and Singh, S; 2008. Public understanding of Science in India. *India, Science and Technology*.

Reddy, V.; Juan, A.; Gastrow, M; Bantwini, B; 2009. *Science and the publics: A review of Public Understand of Science studies*. HSRC, Pretoria.

Reddy V, Gastrow M, Juan A, Roberts B, B; 2013. Public attitudes to science in South Africa. South African Journal of Science Volume 109 | Number 1/2 January/February 2013

Reddy, V.; Juan, A.; Hannan, S.; Arends, F.; Gastrow, M; Roberts, B; 2015. Science Awareness, Attitudes and astronomy: Continuity and Changes South African Social Attitudes Survey 2013. Human Sciences Research Council, 2015. Available online at: http://www.timss-sa.org.za/?wpfb_dl=31

Reser, J. P.; Bradley,G. L.; Glendon, A. I.; Ellul, M. C.; Callaghan, R.; 2012. Public Risk Perceptions, Understandings, and Responses to Climate Change and Natural Disasters in Australia, 2010 and 2011. National Climate Change Adaptation Research Facility, Gold Coast, 245 pp

Rip, A; 1997. "Qualitative Conditions of Scientometrics: The New Challenge". *Scientometrics*, 38 (1), (1997), 7–26.

Roberts, D.A; 1983 Scientific Literacy: towards balance in setting goals for school science programs. A discussion paper for the Science Council of Canada. Ottawa: science council of Canada.

Roberts, D. A. 2007. Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research in science education (pp. 729 – 779). Mahwah, NJ: Erlbaum. Section available online at: http://faculty.education.ufl.edu/tsadler/Roberts-SciLit.pdf. Accessed 15 November 2013

Rokeach, M. (1968). *Beliefs, attitudes, and values: A theory of organization and change*. San Francisco, CA: Jossey-Bass.

Rose, N; 1999. *Powers of Freedom: Reframing Political Thought*. Cambridge, UK: Cambridge University Press. Available online: http://assets.cambridge.org/97805216/50755/sample/9780521650755wsc00.pdf

Royal Society, 1985 *The Public Understanding of Science*. London: Royal Society.

Royal Society, 2007. International Indicators of Science and the Public workshop. Conference Proceeding.

Salvadori, N. 2003. *The Theory of Economic Growth: A Classical Perspective*. Cheltenham: Edward Elgar.

Sapp, G; 1992. Science Literacy: A Discussion and an Information-based Definition. College & Research Libraries. vol. 53 no. 1 21-30. Available online at: http://crl.acrl.org/content/53/1/21.full.pdf+html. Accessed 23 December 2013

Sasol, 2005. *Unlocking the potential wealth of coal.* Publicity Brochure published by Sasol. www.sasol.com/sasol_internet/.../CTL_Brochure_1125921891488.pdf

Scerri, Mario; 2008. "The Parameters of Science and Technology Policy Formulation in South Africa". *African Development Review*. Volume 10, Issue 1, pages 73–89, June 1998

Seekings, J, 2003. "Social Stratification and Inequality in South Africa at the end of Apartheid". CSSR Working Paper No. 31. Centre for Social Science Research. University of Cape Town. Available online at http://cssr.uct.ac.za/sites/cssr.uct.ac.za/files/pubs/wp31.pdf. Accessed 22 April 2013

Shamos, M. H, 1995. “The Myth of Scientific Literacy”. Rutgers University Press. New Jersey.

Shen, B.; 1975. Science literacy: public understanding of science is becoming vitally needed in developing and industrialized countries alike. American Scientist 63 (May-June 1975), 265-268.

Shephard, A; 2003. "Income Inequality under the Labour Government". Briefing Note No. 33. Institute for Fiscal Studies. Available online at: http://www.ifs.org.uk/bns/bn33.pdf. Retrieved 18 January 2013.

Shukla, R.; 2005. India Science Report Science Education, Human Resources and Public Attitude towards Science and Technology. Chapter 4: Public Attitude towards Science and Technology. Available online at: http://www.insaindia.org/pdf/India_Science_report-Main.pdf. Accessed: 13 July 2014.

Shukla, R.; Bauer, M.; 2009. *Construction and Validation of ‘Science Culture Index’: Results from Comparative Analysis of Engagement, Knowledge and Attitudes to Science: India and Europe*. Working Paper No: 100, Royal Society, UK

Singh, S. and Raza, G.; 2012. Shift in Cultural Distance between Science and Public: Evidence of Kumbh Survey Studies. Available online at: http://st.niscair.res.in/publications/shift-cultural-distance-between-science-and-public-evidence-kumbh-survey-studies-0. Accessed 16 July 2014.

Slocum-Gori, S. L.; Zumbo, B. D.; 2011. Assessing the Unidimensionality of Psychological Scales: Using Multiple Criteria from Factor Analysis. Social Indicators Research July 2011, Volume 102, Issue 3, pp 443–461

Smith, L. I; 2002. “A tutorial on Principal Components Analysis”. Online tutorial series. Available at: http://www.cs.otago.ac.nz/cosc453/student_tutorials/principal_components.pdf

Snow, C.P. 1959. Rede Lecture. Cambridge University. Press, Cambridge, England. Available online at: http://s-f-walker.org.uk/pubsebooks/2cultures/Rede-lecture-2-cultures.pdf. Accessed 08 December 2012

Song, J.; Chung, M.; Choi, E.; Kim, L.; Cho, S. K.; 2008. Developing the Indicator System for Diagnosing the National Status Quo of Science Culture. Journal of the Korean association for science education; vol. 28; no. 4; page: 316-330. Translated from Korean to English using https://translate.google.com/

Song, J.; Chung, M.; Choi, E.; Kim, L.; Cho, S. K.; 2011. How to compare the social foundations of science culture: A trial with five cities in Korea. Public Understanding of Science 22: 110

Stanat, P; Artelt, C; Baumert, J; Klieme, E; Neubrand, M; Prenzel, M; Schiefele, U; Schneider, W; 2002. PISA 2000: Overview of the study—Design, method and results. Max Planck Institute for Human Development. Berlin. Available online at: https://www.mpib-berlin.mpg.de/Pisa/PISA-2000_Overview.pdf. Accessed 06 June 2013.

Stastny, K; 2005. Risk Communication and Asymmetric Information in the Case of Mad Cow Disease. Unpublished senior thesis. Available online at: http://tinyurl.com/o99fe4h.Accessed 11 November 2013

Stats Canada, 2013. Scientific Literacy in PISA. Programme for International Student Assessment information website. Direct link: http://www.pisa.gc.ca/eng/science.shtml. Accessed 27 March 2014

StatSA, 2012. Census 2011: Statistical release (Revised). Publication number: P0301.4. Publication date 06 October 2012. Accessed 22 March 2013. Available online at: http://www.statssa.gov.za/Publications/P03014/P030142011.pdf

StatSA, 2013. *Quarterly Labour Force Survey Quarter 1, 2013*. Publication number: P0211. Publication date 06 May 2013. Accessed online http://www.statssa.gov.za/publications/P0211/P02111stQuarter2013.pdf

StatsSA, 2014. “Mid-year population estimates 2014” PO302 Statistics South Africa, Pretoria. Accessed online: http://www.statssa.gov.za/publications/P0302/P03022014.pdf

StatSA, 2016. *Quarterly Labour Force Survey Quarter 1, 2016*. Publication number: P0277. Publication date 04 July 2016. Accessed online http://www.statssa.gov.za/publications/P0277/P0277March2016.pdf

State Council of the People’s Republic of China (2006) *The Outline of the Action Plan for Improving Scientific Literacy for All (From 2006–2010 and then 2010–2020)*. Beijing: The People Press.

Stocklmayer, S & Gilbert, J.K.; 2002. 'New experiences and old knowledge: Towards a model for the personal awareness of science and technology', International Journal of Science Education, 24: 8,

Stokes, D.E. 1997: Pasteur´s Quadrant – Basic Science and Technological Innovation, Washington DC.

Sturgis, P and Allum, N. 2004. “Science in Society: Re-Evaluating the Deficit Model of Public Attitudes.” *Public Understanding of Science.* Vol 13 p 55-74.

Struwig, J. and Roberts, B.; 2011. Heart of the matter nuclear attitudes in South Africa. HSRC review, Vol 10 Number 2. June 2012.

Sun, M; 2010. Science Education and Communication in China: Policies and Measures. China Association for Science and Technology (CAST). Presentation available online at http://cache-www.intel.com/cd/00/00/45/51/455169_455169.pdf. Accessed 28 June 2014

Tardy, C.; 2004. The role of English in scientific communication: Lingua franca or Tyrannosaurus Rex? Journal of English for Academic Purposes 3(3):247-269 · July 2004

The American Association for Public Opinion Research. 2011. Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys. 7th edition. AAPOR.

Thomson, S.; Hillman, K.; Wernert, N.; Schmid, M.; Buckley, S.; Munene, A.; 2011. Highlights from the reports: Monitoring Australian Year 4 student achievement internationally: TIMSS and PIRLS 2011. Report available online at: http://www.acer.edu.au/documents/TIMSS-PIRLS_Australian-Highlights.pdf . Accessed 22 February 2014

Tiley-Nel, S. (Ed). 2010. *Mapungubwe Remembered: A legacy of the University of Pretoria and Mapungubwe*. Chris Van Rensburg Publishing (Pty) Ltd.

Torun-Cumhur Çiçekçi, H; 2007. Innovation: Is the engine for the economic growth? Ege University,Turkey. Accessable online at: http://www.tcmb.gov.tr/yeni/iletisimgm/Innovation.pdf. Accessed 22 July 2013.

Turner, S; 2008. School science and its controversies; or, whatever happened to scientific literacy? Public Understanding of Science 2008 17: 55. Available online at http://pus.sagepub.com/content/17/1/55.full.pdf. Accessed 16 July 2013

UNDP-HDI, 2013. Human Development Report 2013: The Rise of the South: Human Progress in a Diverse World. Published by the United Nations Development Programme (UNDP), New York. Available online at http://hdr.undp.org/en/mediacentre/

United Nations Statistical Services Branch; 2006. Standard Country or Area Codes for Statistical Use. Available online at http://unstats.un.org/unsd/methods/m49/m49.htm. Accessed 14 March 2014.

Van der Berg, S & Louw M., 2003. "Changing patterns of South African income distribution: Towards time series estimates of distribution and poverty". Paper to the Conference of the Economic Society of South Africa, Stellenbosch, 17-19 September 2003. Accessed online on 27-05-2011. Available at http://www.sarpn.org.za/documents/d0000727/P800-Poverty_trends_vdBerg_Louw.pdf

Van der Berg, S; 2010. "Current poverty and income distribution in the context of South African history". Stellenbosch Economic Working Papers: 22/10 October 2010. Accessed online on 13-06-2011. Available at www.ekon.sun.ac.za/wpapers/2010/wp222010/wp-22-2010.pdf

Van Rooyen, C, 2004. "Science not a priority for SA Press". *Science in Africa*. Accessed April 2011. Available at: www.scienceinafrica.co.za/2004/april/pressscience.htm

Van Weijen, D.; 2012. The Language of (Future) Scientific Communication. Research Trends, issue 31 November 2012. Available online at https://www.researchtrends.com/issue-31-november-2012/the-language-of-future-scientific-communication/

Vavi, Z, 2010. *"The legacy of apartheid is still with us"*. COSATU, accessed online 12-06-2011 from: http://www.politicsweb.co.za/politicsweb/view/politicsweb/en/page71654?oid=177433&sn=Detail

Weeks, F. H. The quest for a culture of learning: a South African schools perspective. SA Journal of Education, Vol 32, No 1 (2012). Available online at: http://www.sajournalofeducation.co.za/index.php/saje/article/view/565. Accessed 06 May 2013

Wenning, C.; Wenning-Vieyra, R.; 2009. Teaching High School Physics: A resource for teacher preparation and professional development. Chapter 10: Scientific Literacy The Main Goal Of Science Education. Available online at: http://www.phy.ilstu.edu/~wenning/thsp/chapters/Scientific_Literacy[1].pdf. Accessed 22 April 2013

Wenning, C. J.; 2011. Science literacy: What it is, how to assess it, and a way to achieve it. Illinois State University. Unpublished presentation. Available online at: http://www.phy.ilstu.edu/pte/INDONESIA/G.%20SciLit-What_&_How.pptx. Accessed 06 January 2014.

Worden, N; 1994. The Making of Modern South Africa: Conquest, Apartheid, Democracy. Blackwell Publishers. Edition 5, 2012.

Tavakol, M.; Dennick, R.; 2011. Making sense of Cronbach's alpha. International Journal of Medical Education. 2011; 2:53-55. Available online at: https://www.ijme.net/archive/2/cronbachs-alpha.pdf. Accessed: 23 March 2016

The World Bank, 2011. Purchasing Power Parities and Real Expenditures of World Economies Summary of Results and Findings of the 2011 International Comparison Program. Available online at http://siteresources.worldbank.org/ICPINT/Resources/270056-1183395201801/Summary-of-Results-and-Findings-of-the-2011-International-Comparison-Program.pdf. Accessed 15 June 2014

Thelwall, M.; 2016. Interpreting correlations between citation counts and other indicators. Scientometrics July 2016, Volume 108, Issue 1, pp 337–347

Tredoux, C.; Durrheim, K. (Eds).; 2002. Numbers, hypotheses and conclusions: A course in statistics for the social sciences. Juta: Cape Town.

Turney, J.; 2003. How Greenfield got it wrong. The Guardian, Thursday 17 April 2003. Available online at: http://www.theguardian.com/education/2003/apr/17/research.highereducation1

Venkateswaran, T. V.; 2013. Vigyan Mandir experiment – the first mass scientific literacy effort in India. Conference paper presented at the Fifth International Conference to review research on Science, Technology and Mathematics Education. Homi Bhabha Centre for Science Education, Mumbai, India January 7, 2013 – January 11, 2013. Available online at: http://episteme.hbcse.tifr.res.in/index.php/episteme5/5/paper/view/102. Accessed 01 August 2014.

WikiCommons, 2013. "*South Africa - Location Map (2013) - ZAF - UNOCHA.svg*". Available at Wikipedia Commons at location: https://en.wikipedia.org/wiki/File:South_Africa_-_Location_Map_(2013)_-_ZAF_-_UNOCHA.svg

Williams, W., 2006. Existing National and International Database Comparisons: A regional study of community attitudes and engagement with science and technology in Australia.

Wilson, E. O.; 1998. "Consilience: The Unity Of Knowledge". Vintage Books. New York. Available online at: http://wtf.tw/ref/wilson.pdf

Wilson, J.; Tyedmers, P.; Pelot, R.; 2007. Contrasting and comparing sustainable development indicator metrics Article in Ecological Indicators. Ecological Indicators 7 (2007) 299–314

Wolff, M. R, Barton, A. C; 2004. *Rethinking Scientific Literacy*. Taylor and Francis (Routledge) United Kingdom. Accessed online at Google books

Wu, M. L.; 2009. A Comparison of PISA and TIMSS 2003 achievement results in Mathematics. Prospects. March 2009, Volume 39, Issue 1, pp 33-46. Available online at: http://www.iea.nl/fileadmin/user_upload/IRC/IRC_2008/Papers/IRC2008_Wu.pdf. Accessed 11 November 2013

Wyatt, N.; Stolper, D.; 2013. Science literacy in Australia. Report prepared for: Australian Academy of Science.

Wynne, B. (1992). Public understanding of science research: New horizons or hall of mirrors? Public Understanding of Science, 1(1), 37–43.

Yechury, S; 2008. “Eat your words Mr Bush!”. Hindustan Times, India, May 8 2008. Accessed online 07-06-2011. Available at http://worldmeets.us/hindustantimes000003.shtml#axzz1RdEz5eIj

Zhang, Z and Zhang, J.; 1993. A survey of public scientific literacy in China. Public Understanding of Science January 1993 issue 2, page 21-38.

Ziman, J. 1991. "Public Understanding of Science." *Science, Technology,& Human Values.*16(1): 99-105

Zuzovsky, R.; 1997. Assessing Scientific and Technological Literacy among Sixth Graders in Israel. Studies in Educational Evaluation, vol. 23 number 3

Appendix 1

POPULATION DESCRIPTION

South Africa is a country of 9 provinces as well as multiple cultural and linguistic groupings that form the foundations of an eclectic mix of various segments of the general South African public. Covering an expanse of 1.2 million square-kilometres, the current population of South Africa is estimated at 54 million people (StatsSA, 2014). The country has 3 official capital cities and 4 major metropolitan areas, namely, Johannesburg-Pretoria, Cape Town and Durban, with multiple regional hubs in each province (see Figure A1-1).

Figure A1-1: General map of South African major cities (Source: WikiCommons, 2013)

Among the total population of 54 million people, 30% of South Africans are below the age of 15 years old, while 51% are female and 49% are male. The vast majority of the South African population is therefore between the ages of 18 and 59 years old and, despite large unemployment, many are considered part of the headcounts of economically active South Africans (StatsSA, 2012). This study therefore undertook data collection accessing a nationally representative sample based, in part, on the population profile within the latest available completed South African Census data.

The South African National Census was completed in 2011 and yielded a total national population of 54 002 000 individuals. As 30% of these individuals are aged below 15 years old, the total population that forms the basis of this study is therefore 37 664 000 individuals. While specific sample selection and related information has been reported in Chapter Four this will be briefly recapped in the below section. The survey fieldwork, run by IPSOS, yielded a representative sample of the South African population. A total sample of 4 123 South Africans was interviewed in face-to-face home-based interviews. Sampling units and housing units were identified using established and accepted fieldwork rotation means, while interviewees within the residential units were identified using a selection grid (see chapter 4). These included 2 959 urban and 1 164 rural and deep-rural interviews by fieldwork completion (n = 4 123). Results from the fieldwork were then cleaned and weighted back to the valid population of 37 664 000 individuals from which the sampling frame was developed. The sampling frame was based on the *All Media and Products Survey* (AMPS) sampling frame, which in turn is based on the South African National Census 2011. Following the cleaning process a total of 506 units[148] were found to be *incomplete* or *refused* to participate fully, while a further 131 units were found to be *below the specified age criteria*[149] yielding a final valid sample for this survey of 3 486 individual units. These 3 486 individual reporting units were then weighted by province and estimations for the entire population are provided in figure A1-2 below.

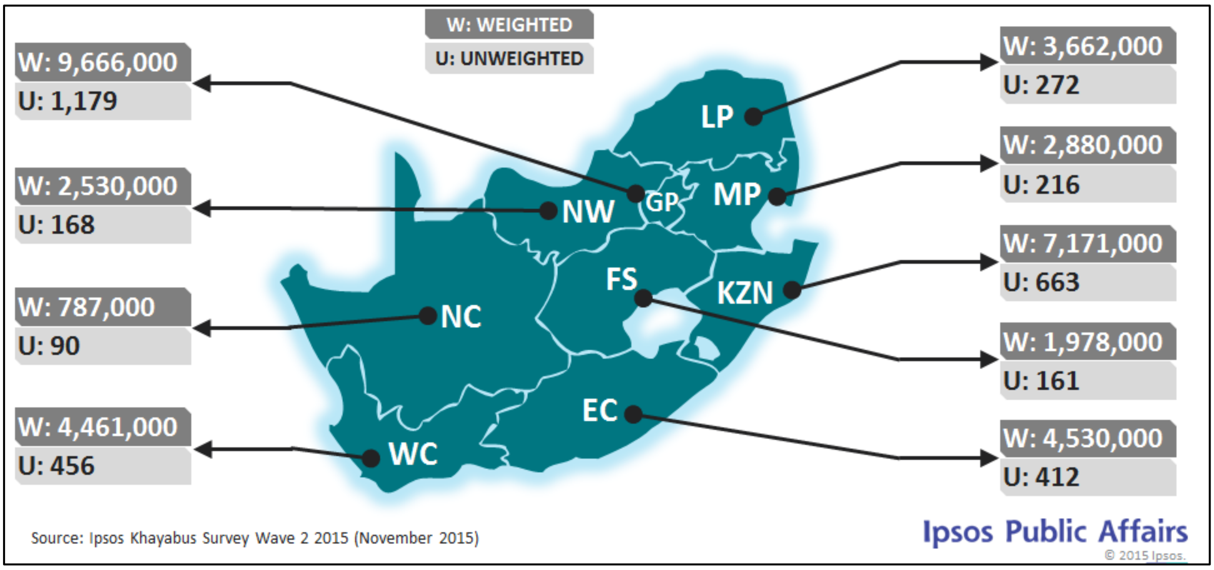


Figure A1-2: Sample and Population per Province, South Africa (Source: With Permission: IPSOS Public Affairs)

As per the population estimates within the national census, each provincial sample cohort was calculated on actual population representation and similarly the sample within in each province reflects the same population demographic profile to ensure representivity. Weights were applied based on in-Province population characteristics such as age, gender, population group, community size and related demographic criteria. Further to this the sample weighting and benchmarking was completed using data from the South African Audience Research Foundation (SARF) called the *All Media and Products Survey* (AMPS). AMPS is a highly respected data source within South Africa and issues two data releases per annum, in their coverage of more than 25 000 individuals in each of the 2 survey waves. The AMPS survey forms the basis of most every large public opinion and consumer

[148] *Units* in this sense implies individuals surveyed
[149] As this is an omnibus survey, the age limitation was only enforced for this study module

insights survey in South Africa and is closely correlated to population distributions within the National Census.

Comparisons between the Khayabus survey sample distribution statistics that of the AMPS survey as well as the National Census data were compared and revealed a high degree of consistency between the population characteristics distribution of the 3 data sets. Presented below are selected items from within the comparison to illustrate the high-degree of consistency between the 3 datasets as well as the overall national representivity achieved in employing the *Khayabus Survey* as the vehicle for the data collection within this study (see Table A1-1 below[150]).

	South African National Distributions		
Gender	**Khayabus 2015 (18+: n= 3 486)**	**AMPS (18+)**	**CENSUS 2011 (18+)**
Male	48.5%	47.8%	47.7%
Female	51.5%	52.2%	52.3%
Total	**100.0%**	**100.0%**	**100.0%**

Race	Khayabus 2015	AMPS	CENSUS 2011*
White	10.4%	10.3%	10.8%
Black	77.5%	77.9%	76.6%
Indian / Asian	2.7%	2.8%	2.9%
Coloured	9.4%	9.1%	9.0%
Total	**100.0%**	**100.0%**	**99.4.0%**

Province	Khayabus 2015	AMPS	CENSUS 2011
Western Cape	12.0%	11.7%	12.1%
Eastern Cape	11.7%	12.0%	11.7%
Northern Cape	2.1%	2.2%	2.2%
Free State	5.0%	5.3%	5.3%
KwaZulu Natal	18.9%	18.7%	18.7%
North West	6.9%	6.8%	6.8%
Gauteng	25.7%	26.3%	26.3%
Mpumalanga	7.9%	7.5%	7.5%
Limpopo	9.8%	9.5%	9.5%
Total	**100.0%**	**100.0%**	**100.0%**

Table A1-1: Metro and Non Metro weighted Sample comparison with AMPS sampling data age 18+ (Source: IPSOS Public Affairs) (*OTHER category in Census 2011 not represented)

As can be seen in table A1-1, small variations do exist between the *Khayabus* as well as the *AMPS* distributions and the National *Census* data. This observed variation is likely as a result of in-field substitutions and sampling error; however results maintain the required level of accuracy and still remain acceptable for its intended application within this study. The detailed statistical considerations and techniques adopted in developing the survey sampling frame as well as the related data sources and benchmarking practices further underpins the overall reliability of the quality of the survey sample presented within the Khayabus Wave 2 of 2015.

[150] Data is weighted and figures represent values for the population not the survey sample

The *American Association for Public Opinion Research* (AAPOR) defines survey response rates to include, "*the number of complete interviews with reporting units divided by the number of eligible reporting units in the sample*" (AAPOR, 2011). The AAPOR further defines 6 categories of response rates, each with varying definitions, depending on the scope and operationalisation of the fieldwork for the research. Within the survey fieldwork a total sample of 4 123 units were interviewed. Accounting for *missing values*, *refusals*, *age cut-offs* (M-R-A) and other non-response categories, all respondents within the 3 617 valid participants completed all question sections within this module, thus yielding a 100% raw-response rate to all survey items. Following the completion of data cleaning and quality assurance procedures the survey yielded a final valid sample of 3 486 individuals, as well as a survey response rate of 96.38 %. As the Khayabus survey has set deliverables on the sample size, measures are in place to allow appropriate respondent substitution to ensure that the final survey size meets the design specifications.

Question Section	Sample	M-R-A Values*	Valid Responses	Raw Response rate	Total Response Rate
SECTION A: Scientific knowledge	**3 617**	**131**	**3 486**	**100%**	**96.38%**
SECTION B: Attitude to science**	**3 617**	**131**	**3 486**	**100%**	**96.38%**
SECTION C: Interest in science	**3 617**	**131**	**3 486**	**100%**	**96.38%**
SECTION D: Informedness about science	**3 617**	**131**	**3 486**	**100%**	**96.38%**
SECTION E: Information sources about science	**3 617**	**131**	**3 486**	**100%**	**96.38%**
SECTION F: Participation in science engagement activities	**3 617**	**131**	**3 486**	**100%**	**96.38%**

* M-R-A Values: Missing, Refusals, Age criteria cut -off

Table A1-2: Response rates for the Public Understanding of Science Khayabus Survey Module, 2015 wave 2

Table A1-2 details the response rates for each section of the questionnaire, providing both *raw response rate*[151] as well as *total survey response rates*[152]. This metadata reveals that of the individuals that responded to the Khayabus survey, respondents answering this particular questionnaire module completed all required questions. The next section will provide additional insight into the sample composition, geographic location as well as demographic analysis on selected variables.

5.3 DEMOGRAPHIC PROFILE of SAMPLE

The previous section detailed the sample composition and addressed issues pertaining to national representivity of the data. The following section will explore selected demographic variables within the sample to develop some insights into the demographic context of the overall sample. Within the demographic data collected in the Khayabus Survey, 7 items will be explored in this section,

[151] *Raw response rate* based on *Total Response / Total Surveyed Units*.
[152] *Total survey response rate* is the response rate for *Total Valid Response / Total Responses per Question Set*.

including: *province, gender, population group, age, working status*, *levels of education* as well as *household income*.

Within this study design respondents from all 9 South African provinces are represented within the coverage footprint as detailed in Table A1-33. The majority of respondents were from the Gauteng province (32.5%), followed by KwaZulu Natal (18.3%), the Western Cape (12.8%) and the Eastern Cape Province (11.2%). The provincial boundaries of these South African provinces are home to the five major Metropolitan areas namely Johannesburg-Pretoria, Cape Town, Durban and Port Elizabeth. Combined, these 4 provincial areas account for 74.9% of the total sample covered in the Khayabus Survey, while the remaining 5 provinces jointly account for the remaining 25.1% of respondents.

	Frequency	Percent	Valid %	Cumulative %
WESTERN CAPE	447	12.8	12.8	12.8
EASTERN CAPE	390	11.2	11.2	24.0
NORTHERN CAPE	85	2.4	2.4	26.4
FREE STATE	149	4.3	4.3	30.7
KWAZULU NATAL	639	18.3	18.3	49.1
NORTH WEST	167	4.8	4.8	53.8
GAUTENG	1134	32.5	32.5	86.4
MPUMALANGA	212	6.1	6.1	92.5
LIMPOPO	263	7.5	7.5	100.0
Total	**3 486**	**100.0**	**100.0**	

Table A1-3: Provincial representation in Khayabus wave 2, 2015

Contained within the total sample of 3 486 participants, 56.8% were from *metropolitan* areas, 4.8% were from *cities* and 4.3% from *large towns*. These areas combined account for 65.9% of total responses to the survey, while 9.0% of responses were obtained within *small towns* and *villages*. Further to the above, responses were collected from *rural* and *deep rural* areas across all 9 provinces, which combined accounted for 34.1% of the total survey response (See Table A1-4).

QUESTIONNAIRE CATEGORIES		
Questionnaire Categories	**Frequency**	**%**
CITY	166	4.8
LARGE TOWN	151	4.3
METRO	1 980	56.8
SMALL TOWN	205	5.9
RURAL	875	25.1
VILLAGE	109	3.1
Total	**3 486**	**100.0**

Rural- Urban		
Recoded Variable	**Frequency**	**%**
Urban	2 297	65.9%
Rural	1 189	34.1%
Total	**3 486**	**100.0%**

Table A1-4: Total sample by geographic area type in Khayabus wave 2, 2015

These 6 *community size* clusters were recoded, using the *Recode* facility within SPSS 24.0 to create a new variable called *Rural-Urban*. The recoding was achieved by combining the responses for *metropolitan* areas, *cities* and *large towns* as a single *urban* classification. Similarly the responses under the questionnaire categories *small towns*[153], *rural* and *village* were classified in a single *rural* classification. Results for the recoded classifications of *community size* are presented in Table A1-4 above.

The gender distribution within the sample is reflective of the National Census 2011. Among the 3 486 participants in this study *females* comprised 50.1%, while *males* accounted for 49.9% of the total sample. Table A1-5 below presents the total sample of 3 486 individuals split by gender classification.

	Frequency	Percent	Valid %	Cumulative %
Female	1 747	50.1	50.1	50.1
Male	1 739	49.9	49.9	100.0
Total	**3 486**	**100.0**	**100.0**	

Table A1-5: Total sample by Gender distribution in Khayabus wave 2, 2015

Similar to the geographical splits by province, overlaying gender characteristics within provincial data reveals that the gender representation per province continues to reflect the National Census population characteristic[154]. Gauteng province achieved the largest overall contribution to the national population despite being the smallest geographical area. Data from within the survey for the Gauteng province indicates that of the 1 134 individuals surveyed in the province, 575 were *female* (50.7%) while 559 were *male* (49.3%). Within KwaZulu-Natal, the survey recorded more males (50.5%) than females (49.5%), while within the Western Cape; a similar pattern emerged, with 49.2% of respondents being female, while 50.8% were male. The province with the biggest difference between the gender groupings was Mpumalanga, where 51.4% of respondents were female (109) and 48.6% were male (103), a value consistent with Census 2011 data for this province (see Table A1-6).

[153] Due to the definition applied for *Small Town*, these areas have been grouped under *Rural*, as they represent commercial centres within predominantly Rural and agricultural areas

[154] For those South Africans aged 18 years and older N = 37 664 000

	TOTAL	Female		Male	
		COUNT	%	COUNT	%
Eastern Cape	390	194	49.7%	196	50.3%
Free State	149	75	50.3%	74	49.7%
Gauteng	1 134	575	50.7%	559	49.3%
KwaZulu-Natal	639	316	49.5%	323	50.5%
Limpopo	263	131	49.8%	132	50.2%
Mpumalanga	212	109	51.4%	103	48.6%
North West	167	84	50.3%	83	49.7%
Northern Cape	85	43	50.6%	42	49.4%
Western Cape	447	220	49.2%	227	50.8%
Total	**3 486**	**1 747**	**50.1%**	**1 739**	**49.9%**

Table A1-6: Total sample by Gender and Province in Khayabus wave 2, 2015

South Africa is a country that still carries many of the legacy influences of its former apartheid system of racial segregation, influencing numerous aspects of contemporary life. As a result of this racially based population classification under the apartheid government, in present day South Africa major population classifications still reflect these grouping classifications. In contemporary South Africa while income inequality, access to resources and infrastructure as well as social services is no longer planned along racial classifications, many areas remain racially segmented, in geographic and demographic terms, as a result of the legacy impacts of apartheid, poverty and social engineering. As such the below discussion of *population groups* is presented from the premise that as a result of the many legacy impacts and inequalities stemming from the apartheid past, identifying areas requiring greater intervention remains valuable, and understanding its racial dynamics would continue to be useful within the South African context.

	Frequency	Percent	Valid %
Black	2 523	72.4	72.4
White	408	11.7	11.7
Indian / Asian	121	3.5	3.5
Coloured	434	12.4	12.4
Total	**3 486**	**100.0**	**100.0**

Table A1-7: Total sample by Population Group breakdown in Khayabus wave 2, 2015

Within the total sample of 3 486 participants, the general *population group* profile is presented in Table 5.7. *Black* South Africans represented 72.4% of the total sample, followed by *coloured* participants (12.4%), *white* (11.7%) and *Indian / Asian* participants (3.5%). These population groups analysed alongside the variable of *Gender* highlights the *Gendered* composition of the population groups discussed (see table A1-8). Specific in-group variances were noted with respect to *gender* and *population group*; however this broadly reflects the overall National demographic profile in South Africa.

	Total	Female		Male	
		Count	%	Count	%
White	408	203	49.8%	205	50.2%
Black	2 523	1 267	50.2%	1 256	49.8%
Indian / Asian	121	58	47.9%	63	52.1%
Coloured	434	219	50.5%	215	49.5%
Total	**3 486**	**1 747**	**50.1%**	**1 739**	**49.9%**

Table A1-8: Total sample by Population Group and Gender breakdown in Khayabus wave 2, 2015

Previous studies on *scientific literacy* and the *public understanding of science* have noted the influence of respondent *age* on general survey results (see Chapter 3). Within the *Khayabus* survey respondents were asked to provide an indication of their *age*. South Africa has a large youth population, with more than 60% of the national population being below the age of 35 years (StatsSA, 2014). Within the current research, only respondents 18 years and older were considered, however a profile similar to the national Census emerges, when looking at the age data from within the survey results. Table A1-9 defines the age profile of survey participants within the 11 questionnaire age group clusters.

	Frequency	Percent	Valid %	Cumulative %
18 – 19 years	170	4.9	4.9	4.9
20 – 24 years	563	16.2	16.2	21.0
25 – 29 years	538	15.4	15.4	36.5
30 – 34 years	526	15.1	15.1	51.5
35 – 39 years	430	12.3	12.3	63.9
40 – 44 years	334	9.6	9.6	73.5
45 – 49 years	264	7.6	7.6	81.0
50 – 54 years	199	5.7	5.7	86.7
55 – 59 years	173	5.0	5.0	91.7
60 – 64 years	123	3.5	3.5	95.2
65+ years	152	4.4	4.4	99.6
Refusal	14	0.4	0.4	100.0
Total	**3 486**	**100.0**	**100.0**	

Table A1-9: Total sample by self-reported age groupings in Khayabus wave 2, 2015

As with the *rural-urban* variable, the *Age* variable was recoded within SPSS as a data reduction strategy toward streamlining the analysis and presenting more meaningful analysis of this important variable. The original 11 age categories presented in table A1-9, were recoded into a *NEW AGE* variable that had now combined these into 6 age categories. To achieve this, the *18 and 19 years* category was retained and renamed *< 20 years*, while every category beyond this was defined into decade segments until the age of 59 years. Participants reporting age in excess of 59 years old were categorised into a category called *60+ years*. These recoded age categories are presented in table A1-10 below.

	Frequency	Percent	Valid	Cumulative
< 20 years	170	4.9	4.9	4.9
20-29 years	1 101	31.6	31.7	36.6
30-39 years	956	27.4	27.5	64.1
40-49 years	598	17.2	17.2	81.4
50-59 years	372	10.7	10.7	92.1
60+ years	275	7.9	7.9	100.0
Total	**3 472**	**99.6**	**100.0**	
Missing	14	0.4		
Total	**3 486**	**100.0**		

Table A1-10: Recoded Age categories in Khayabus wave 2, 2015

Age grouping clusters within the *Khayabus* Survey similarly identifies the combined age groups 18-35 years old as being the largest segment of the sample within this study, accounting for 51.5% of the total response. Within the above recoded age cohorts, adults aged between 20 and 29 years account for 31.6% of the total sample of 3 486 participants. Individuals between the ages of 30 and 39 years account for 27.4%, while those reporting in the category 40-49 years made up 17.2% of all fieldwork responses. Respondents older than 50 years accounted for 18.6% of total response. Within the total sample, 14 respondents selected the *refuse* option and did not divulge their age[155] (0.4%).

The very large youth population in South Africa is not uncommon within developing nations; however an additional consideration would be the current employment status of these individuals. Employment status can be seen as an indicator of economic productivity within this large youth segment with the national population. Data from within this study reveals respondent working life status through the use of 7 categories describing current *employment status* (see table A1-11).

	Frequency	Percent	Valid %
Working full-time	1 265	36.3	36.3
Working part-time	288	8.3	8.3
Not Working - Housewife	152	4.4	4.4
Not Working - Student	274	7.9	7.9
Not Working - Retired	228	6.5	6.5
Unemployed - seeking work	1 081	31.0	31.0
Unemployed - not seeking work	198	5.7	5.7
Total	**3 486**	**100.0**	**100.0**

Table A1-11: Total sample by employment status groupings in Khayabus wave 2, 2015

Individuals reporting some form of employment accounted for 44.5% of total response, comprising of 36.3% *working full-time* while a further 8.3% report being *employed in a part-time* capacity. Parallel to this is the finding that 36.7% of individuals in this survey report being *unemployed*, 31.0% of which are active job seekers while 5.7% are currently not seeking employment. Within the

155 These include missing values and refusals.

remaining 18.8% of respondents reporting *no current employment*, 4.4% were *home-based*[156], 7.9% were *students* and 6.5% report being *retired*.

Total Unemployed: 1 279 (36.7%)	GENDER		AGE						
	Female	Male	<20 YEARS	20-29 YEARS	30-39 YEARS	40-49 YEARS	50-59 YEARS	60+ YEARS	Total
Unemployed - seeking work	607	474	2.1%	47.0%	29.9%	14.1%	5.8%	1.0%	100%
Unemployed - not seeking work	124	74	3.6%	15.9%	10.8%	15.9%	32.8%	21.0%	100%
Total	**731**	**548**	**4.9%**	**31.7%**	**27.5%**	**17.2%**	**10.7%**	**7.9%**	**100%**

Table A1-12: Respondents reporting unemployment status in Khayabus wave 2, 2015

Among the 1 279 respondents reporting *unemployment*, but *actively seeking work*, 607 were female while 474 were male. Within those reporting *unemployment*, but *not seeking work* 124 were female and 74 were male. These results indicate that a larger share of unemployed individuals is female, whether actively engaged in employment seeking or not. Among individuals reporting *unemployment* though still actively *seeking work*, 79% are below the age of 39 years, while those older account for the remaining 21.0% of unemployed job seekers. This profile is very different when looking at respondents reporting *unemployment* and *not actively seeing work* with 69.7% of individuals reporting within this category being 40 years and older.

Recoding of the *EMPLOYMENT* variable as a data reduction requirement yielded 3 categories in a new variable called *EMPLOYMENT_RECODED*. The questionnaire categories for *Working full-time* and *Working part-time* were combined into an *EMPLOYED* category containing 1 553 respondents (44.5%). The categories for *Unemployed - looking for work* and *Unemployed - not looking for work* were combined yielding a new category called *UNEMPLOYED* representing 36.7% of the valid sample (1 279). The 3 questionnaire categories for *Not Working*, as a *Housewife, Student or Retiree* were combined into an *OTHER (Not working)* category accounting for the remainder of the sample (18.8%).

	Frequency	Percent	Valid Percent	Cumulative Percent
Employed	1553	44.5	44.5	44.5
Unemployed	1279	36.7	36.7	81.2
Other (Not Working)	654	18.8	18.8	**100.0**
Total	**3486**	**100.0**	**100.0**	

Table A1-13: Respondents reporting unemployment status in Khayabus wave 2, 2015

A further demographic characteristic that influences the *public understanding of science* and provides additional insight into the sample and population characteristics is the *level of educational attainment*. Respondents were asked to report their *highest level of educational attainment* under

[156] Housewives, care-givers, unpaid domestic work etc.

12 questionnaire categories from *No Schooling* to *Completed University Degree*, with a category provided to capture *other* responses[157]. Certificates and Technikon qualifications were classified independently. As before, data reduction techniques were applied and recoding of the education variable was performed to create 7 categories of *educational attainment* as represented in table A1-14a.

No schooling	No schooling
Some primary school	Primary School
Primary school completed	
Some high school	Some High School
Matric / Grade 12 completed	Matric completed
Artisan's certificate completed	Certificate / Diploma completed
Technikon diploma/degree	
University degree completed	University Degree completed
Professional	Other
Technical	
Secretarial	
Other(Specify)	

Table A1-14a: Recoding of educational attainment variable in Khayabus wave 2, 2015

	Frequency	Percent	Valid %	Cumulative %
No schooling	36	1.0%	1.0%	1.0%
Primary School	231	6.6%	6.6%	7.7%
Some High School	1 102	31.6%	31.6%	39.3%
Matric completed	1 578	45.3%	45.3%	84.5%
Certificate / Diploma completed	351	10.1%	10.1%	94.6%
University Degree completed	125	3.6%	3.6%	98.2%
Other	63	1.8%	1.8%	100.0%
TOTAL	**3 486**	**100.0%**	**100.0%**	

Table A1-14b: Respondents educational attainment in Khayabus wave 2, 2015

Included within the 3 486 respondents in this survey, very few respondents reported having *no education* (1.0%); while 6.6% reported having completed *Primary School*[158]*.* The vast majority of respondents have attended high school (76.9%), however among these 31.6% report having *not completed high school*, while 45.3% report having completed *Grade 12* (Matric) successfully. With respect to post-schooling qualifications, 10.1% report having completed a *Certificate, Diploma* or similar *Artisanal qualification*, while only 3.6% report having completed a *University degree*. Among the total number of respondents, 63 (1.8%) reported qualifications not listed within these groups and classified under the grouping *Other*.

These *Educational Attainment* groups were further reduced to allow for more meaningful categories within the data analysis phase. Ultimately 3 categories of *Educational Attainment* were obtained, by

[157] This includes *vocational training*, *diplomas* and *other* qualifications not listed in the 8 categories
[158] In South Africa this covers grades 1 to grade 7

combining all responses on either side of *Matric Completed*, and are represented in table A1-14c below:

	Frequency	Percent	Valid Percent	Cumulative Percent
Pre-Matric	1369	39.3	39.3	39.3
Matric Completed	1578	45.3	45.3	84.5
Post-Matric	539	15.5	15.5	**100.0**
Total	**3486**	**100.0**	**100.0**	

Table A1-14c: Recoded *EDUCATIONAL ATTAINMENT* classifications

As seen in the Census 2011 data, *population group* does impact *educational attainment*, wherein more *black* and *coloured* respondents report lower levels of educational attainment, compared to other race groups, and similarly with post-schooling qualifications, fewer *black* and *coloured* respondents report within this category compared to *Indian* and *white* respondents (StatsSA, 2011).

Related to these demographic variables of *education* and *employment* are matters pertaining to income. South Africa, with a Gini coefficient of 63.1, is a country with among the highest levels of income inequality in the world (World Bank, 2011). Profiling household income of respondents within the *Khayabus* survey, 8 categories were achieved, ranging from *No household income* to income *exceeding R 40 000* per month.

	Frequency	Percent	Valid %	Cumulative %
R 40 000 +	94	2.7	2.7	2.7
R 30 000 – R 39 999	51	1.5	1.5	4.2
R 20 000 – R 29 999	133	3.8	3.8	8.0
R 10 000 – R 19 999	364	10.4	10.4	18.4
R 5 000 – R 9 999	639	18.3	18.3	36.7
R 0 001 – R 4 999	945	27.1	27.1	63.9
No household income	45	1.3	1.3	65.1
No answer	1 215	34.9	34.9	100.0
Total	**3 486**	**100.0**	**100.0**	

Table A1-15a: Respondents reported household income in Khayabus wave 2, 2015

Income levels within the survey sample report that combined, 57.2% of respondents have a household income of between R 0 001 and R 19 999 per month[159]. Only 10.4% of these households earn between R 10 000 and R 19 999 per month, while the majority within the remaining 45.4% report household income between R 0 001 and R 9 999 per month. Among households at the upper end of the income spectrum, 5.3% of respondents report average household income between R 20 000 and R 39 999 per month, while a very small group of individuals report income exceeding R 40 000 per month (2.7%). Very few respondents indicated *No Household Income* (1.3%), however a

[159] This is not personal income, but combined household income

large proportion of the sample elected to not report on household income (35.2%), which is not unexpected within surveys of this nature. Categories of monthly household income were recoded for ease of analysis and a new variable called *DEMOG_3_HH_INCOME* was created yielding 3 categories of *Household Income* (table A1-15b).

	Frequency	Percent	Valid Percent	Cumulative Percent
Low Income (Less Than R 10 000)	1629	46.7	71.7	71.7
Moderate Income (Between R 10 000 – R 20 000)	497	14.3	21.9	93.6
High Income (R 30 000+)	145	4.2	6.4	**100.0**
Valid	2271	65.1	**100.0**	
Missing	1215	34.9		
TOTAL	**3486**	**100.0**		

Table A1-15b: Revised *Household Income* variable categories

Household income was higher for respondents reporting *full time employment* and decreased with individuals reporting *part-time* and other employment categories. Similarly, *population group* did display some influence on household income levels with *white* respondents reporting more frequently into the higher income groupings, while *black* and *coloured* respondents similarly report more often into the lower income groupings[160]. The relationship between educational attainment and household income is further noted here as individuals reporting higher *educational attainment* similarly report higher *household income*, compared to those respondents reporting lesser *educational attainment*.

The above section presented an overall sample and demographic profile from within a selection of salient variables within the 2015 wave 2 of the Khayabus survey. These demographic variables influence the results of this research at multiple levels, which will be discussed within the next section, exploring the results of the South African *Public Understating of Science* from within survey module.

[160] This is not the rule, but a general observation as in certain cases black household do report into the higher income categories; however across the entire sample, and within the Census (2011) the relationship between income and population group is noted.

Appendix 2

Knowledge of science: Reliability analyses

The analysis will be presented within this chapter along 6 sub-sections as per the questionnaire item areas. Each of the 6 question sets within the *Khayabus Survey* module has been analysed along the specific demographic variables to understanding the influence of these factors on each facet of the South African public understanding of science. Significance testing was performed on all cross-tabulations to determine statistical independence.

QUESTIONNAIRE ITEMS

The l*evel of scientific knowledge* among a representative sample of the South African public was assessed using a 9-item question set as previously discussed, but will be briefly revisited below[161]. Questions were developed or adopted from various sources and following a field testing and pilot phase, a final 9-item question set was produced (see table A2-1 & correct response in table A2-1-2).

QUESTIONNAIRE ITEM	TRUE	FALSE	D/K
In the majority of cases, HIV causes AIDS in humans	1	2	8
Lightning never strikes the same place twice	1	2	8
South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	1	2	8
The continents which we live on are continually moving due to forces deep within the Earth	1	2	8
The price of petrol in South Africa is NOT influenced by the price of crude oil	1	2	8
Schizophrenia is the same as Multiple Personality disorder	1	2	8
The father carries the genetic material that will determine if a baby is a boy or a girl	1	2	8
The earth's climate has NOT changed over millions of years	1	2	8
The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	1	2	8

Table A2-1: 9-item *Science Knowledge* question set in Khayabus wave 2, 2015

	SCIENTIFICALLY CORRECT RESPONSES	TRUE	FALSE
1	In the majority of cases, HIV causes AIDS in humans	TRUE	
2	Lightning never strikes the same place twice		FALSE
3	South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	TRUE	
4	The continents which we live on are continually moving due to forces deep within the Earth	TRUE	
5	The price of petrol in South Africa is NOT influenced by the price of crude oil		FALSE
6	Schizophrenia is the same thing as Multiple Personality disorder		FALSE
7	The father carries the genetic material that will determine if a baby is a boy or a girl	TRUE	
8	The earth's climate has NOT changed over millions of years		FALSE
9	The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life		FALSE

Table A2-1-2: *Scientifically Correct* response to 9-item *Science Knowledge* question set

Each of the items was selected based on a process of understanding the actual self-reported *interest* in science held by members of the South African public[162] as well as an analysis into the source-

[161] See chapter 4: Questionnaire Design and Item Selection.
[162] See references in Chapter 4

scientific fields from which the selected *interest* areas were derived. These *interest* areas and science subject categories were then combined and populated with questionnaire items that reflect the combination of these *science subject* areas as well as the identified *interest* areas (see table A2-2). These *interest* / *knowledge* areas include *Biological Science – Medical, Biological Science – Genetics, Physical Science – Electricity, Physical Science – Geology, Social Science – History, Social Science – Economics, Social Science – Psychology, Earth Science - Climate Change* as well as *Astronomy – Square Kilometre Array*. Table A2-2 below highlights each science subject area and the corresponding question within the 9-item *Science Knowledge* question set.

In the majority of cases, HIV causes AIDS in humans	**BIOLOGICAL SCIENCE - MEDICAL**
Lightning never strikes the same place twice	**PHYSICAL SCIENCE - ELECTRICITY**
South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	**SOCIAL SCIENCE - HISTORY**
The continents which we live on are continually moving due to forces deep within the Earth	**PHYSICAL SCIENCE - GEOLOGY**
The price of petrol in South Africa is NOT influenced by the price of crude oil	**SOCIAL SCIENCE - ECONOMICS**
Schizophrenia is the same as Multiple Personality disorder	**SOCIAL SCIENCE - PSYCHOLOGY**
The father carries the genetic material that will determine if a baby is a boy or a girl	**BIOLOGICAL SCIENCE – GENETICS**
The earth's climate has NOT changed over millions of years	**EARTH SCIENCE - CLIMATE CHANGE**
The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	**ASTRONOMY - SKA**

Table A2-2: *Science Knowledge* question bank with science subject knowledge / interest areas in Khayabus wave 2, 2015

Each of the science subject / interest areas was selected in order to ensure that the science-knowledge question set included the widest definition of science and related science knowledge. The broad subject categories selected allows this research to examine the South African *public understanding of science* within a social context, while simultaneously covering a broader area of *scientific knowledge* than in previous research of this nature. Understanding of science is as much a manner of applying logic as it is recalling factual information. As such selected questions were phrased in the negative in order to test this ability within the general population.

Each respondent in the total sample of 3 486 provided a response to each of the nine (9) *Science Knowledge* items, within the three (3) questionnaire response options. These responses were later recoded as *scientifically correct* or *scientifically incorrect*, based on the documented scientifically correct response to the items in table A2-1-2. Within each item the frequency of *don't know* selections varied, yielding 920 individuals that selected this option across the 9 items. However within these, 298 respondents selected a *don't know* response for each of the 9 items, and these were considered invalid.

QUESTIONNAIRE RESPONSE	TRUE	FALSE	D/K	TOTAL	TRUE	FALSE	D/K
ITEM 1: BIOLOGICAL SCIENCE - MEDICAL (HIV)	2350	651	485	3486	67.4%	18.7%	13.9%
ITEM 2: PHYSICAL SCIENCE - ELECTRICITY (LIGHTNING)	1575	1141	770	3486	45.2%	32.7%	22.1%
ITEM 3: SOCIAL SCIENCE - HISTORY (SA NUCLEAR WEAPONS)	1378	951	1157	3486	39.5%	27.3%	33.2%
ITEM 4: PHYSICAL SCIENCE - GEOLOGY (PLATE TECTONICS)	1609	869	1008	3486	46.2%	24.9%	28.9%
ITEM 5: SOCIAL SCIENCE - ECONOMICS (SA FUEL PRICE)	1422	1238	826	3486	40.8%	35.5%	23.7%
ITEM 6: SOCIAL SCIENCE - PSYCHOLOGY (SCHIZOPHRENIA)	1463	851	1172	3486	42.0%	24.4%	33.6%
ITEM 7: BIOLOGICAL SCIENCE – GENETICS (INFANT SEX AT BIRTH)	1624	1156	706	3486	46.6%	33.2%	20.3%
ITEM 8: EARTH SCIENCE - CLIMATE CHANGE (CLIMATE CHANGE)	1179	1454	853	3486	33.8%	41.7%	24.5%
ITEM 9: ASTRONOMY - SKA	1194	990	1302	3486	34.3%	28.4%	37.3%

Table A2-2-2: Questionnaire Response per item (Science Knowledge)

RECODING and DATA TREATMENT

The items forming the Science Knowledge assessment question set required a single true / false response within the questionnaire. Valid item responses were either true or false, requiring post-hoc recoding of the responses to allow for the extraction and analysis within in more meaningful categories. Items were recoded into two new data categories, *scientifically valid* and *scientifically invalid*, while the *don't know* response option was maintained. Later within the analysis the "*don't know*" category was considered *invalid* and the total response per each of the remaining categories was rebased to obtain valid percentages (where appropriate). All 3 486 valid respondents provided a response to each of the 9 items within this question set.

RELIABILITY of SCIENCE KNOWLEDGE QUESTION SET

The reliability of the 9-item *Science Knowledge* question set was assessed in order to verify that the question set (and later the index) is consistently measuring the required construct. The Cronbach's Alpha was identified as a means to assess the internal consistency of the question set through comparison of the correlation between the individual constituent items. The split-half reliability of the scale and was calculated using the *Reliability Testing* functionality within in SPSS. As all items within this question set were assessed on a dichotomous (true – false) response scale, directionality of each item did not require any additional rescoring of the data. The SPSS outputs produced a correlation matrix for each of the 9 variables within the *Science Knowledge question set*, presented in table 5.17 below.

	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9
ITEM 1: 'In the majority of cases, HIV causes AIDS in humans'	**1.000**								
ITEM 2: Lightning never strikes the same place twice	.562	**1.000**							
ITEM 3: South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	.433	.566	**1.000**						
ITEM 4: The continents which we live on are continually moving due to forces deep within the Earth	.463	.546	.689	**1.000**					
ITEM 5: The price of petrol in South Africa is NOT influenced by the price of crude oil	.489	.535	.567	.605	**1.000**				
ITEM 6: Schizophrenia is the same as Multiple Personality disorder	.406	.442	.516	.563	.590	**1.000**			
ITEM 7: The father carries the genetic material that will determine if a baby is a boy or a girl	.500	.532	.492	.493	.530	.487	**1.000**		
ITEM 8: The earth's climate has NOT changed over millions of years	.511	.539	.571	.608	.562	.570	.552	**1.000**	
ITEM 9: The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	.384	.490	.607	.597	.520	.590	.457	.598	**1.000**

Table A2-3: Reliability Analysis Inter-Item Correlation matrix: *Science Knowledge* question set in Khayabus wave 2, 2015

The *Inter-Item Correlation* matrix assesses the reliability of scores for each item within the scale by comparing each participant item score to every other item score within the scale. Inter-Item Correlation provides an accurate assessment of item redundancy, as an indication of the degree to which items within the scale measures the same construct (Cohen & Swerdlik, 2005, in Piedmont, 2014). Items scoring below the threshold value are to be considered redundant and should be removed from the question set, while items scoring above the threshold could be further considered for inclusion. Independently, Everet (2002) and Field (2005) have indicated that any items with correlation values below 0.300 should be considered candidates for removal as they do not relate favourably to other items within the question set. Table A2-4 provides the correlations for each of the 9 items within the question set, all of which are above the threshold used (0.300). As a result of this evidence, all 9 items were thus considered to be favourably related and further reliability analysis was then performed.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.911	.911	9

Table A2-4: Reliability Statistics: *Science Knowledge* question set in Khayabus wave 2, 2015

The reliability statistics for the Science Knowledge question set was computed and revealed a high internal consistency of 0.911. Table A2-5 presents the results for the *Item Total Statistics* for the *Science Knowledge* question set. Particularly important are the values in the column headed *Corrected Item-Total Correlation*, which provides the correlations between scores for each questionnaire item. All 9 items within the questionnaire achieved high correlations, between 0.60 and 0.75 indicating high consistency across all items within the question set. The column headed *Cronbach's Alpha if Item Deleted* provides an indication of the impact each item has on the overall Cronbach's Alpha score (see table 5.18) should that item be deleted. All values within the scale are between 0.90 and 0.91 equal to, or marginally less than the stated Cronbach's Alpha and thus would not change the reliability of the scale, if deleted.

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
In the majority of cases, HIV causes AIDS in humans'	26.13	338.48	**0.60**	0.41	**0.91**
Lightning never strikes the same place twice	25.42	321.41	**0.68**	0.50	**0.90**
South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	24.70	306.56	**0.73**	0.58	**0.90**
The continents which we live on are continually moving due to forces deep within the Earth	25.02	306.89	**0.75**	0.60	**0.90**
The price of petrol in South Africa is NOT influenced by the price of crude oil	25.28	316.53	**0.72**	0.53	**0.90**
Schizophrenia is the same as Multiple Personality disorder	24.70	310.81	**0.68**	0.50	**0.90**
The father carries the genetic material that will determine if a baby is a boy or a girl	25.54	326.19	**0.65**	0.44	**0.90**
The earth's climate has NOT changed over millions of years	25.16	314.91	**0.74**	0.55	**0.90**
The main purpose of the Square Kilometre Array (SKA) radio telescopes is to search for extra-terrestrial life	24.39	308.20	**0.70**	0.52	**0.90**

Table A2-5: Reliability Analysis Item Total statistics: *Science Knowledge* question set in Khayabus wave 2, 2015

All items correlated well to the complete question set, with the lowest correlation being equal to 0.60. These results indicate that the 9 items *Science Knowledge* question set retains a high internal consistency and therefore provides a reliable measure of *scientific knowledge* within this questionnaire, achieving a Cronbach's Alpha of 0.911. This result confirms the assumption that each of the 9 items reflects a key concept within each field of science concerned, and although distinct factually, conceptually provides an overall assessment of *scientific knowledge* across multiple fields of science for each respondent.

Knowledge assessment tests, such as the questions in the *scientific knowledge* question set further item analysis procedures include *Item-difficulty* and *item-discrimination* testing. Item-difficulty procedures provide an assessment of how challenging the items were for respondents to complete by producing a ratio of respondents selecting the correct response. Within each of the 9 items, scientifically valid responses were computed as a proportion of the total sample (see chart A2-1).

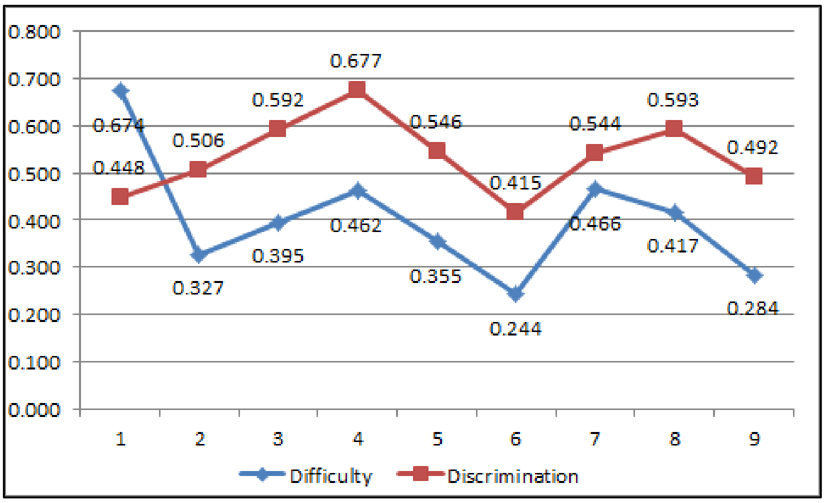


Chart 5.1: Item Difficulty and Discrimination statistics: *Science Knowledge* question (x-axis = item number)

Tredoux and Durrhiem (2002) suggest that in general items producing a difficulty index ratio of between 0.300 and 0.700 should be retained as these provide an acceptable level of difficulty among the population concerned. Chart A2-1 indicates that all items within the *science knowledge* question set produce proportions within this range. Item 6, the question relating to the area of psychology[163] produced the lowest overall scientifically valid response, corresponding to a difficulty index proportion of 0.244. While this is below the established cut-off of 0.300, it was retained for its conceptual and discriminatory value to the question set.

The *item-discrimination index* indicates the degree of score differentiation on each item for *high-scoring respondents* and *low-scoring respondents*. This implies that optimal knowledge-assessment questionnaire items should adequately differentiate between respondents with *high-knowledge* and *low-knowledge*. The *discrimination index* uses mathematical difference between the top-scoring 25% of the sample and the bottom-scoring 25% of the sample, which is then divided by the total number

[163] Item text: *Schizophrenia is the same as Multiple Personality disorder*

of individuals in either 25% group (Tredoux and Durrhiem; 2002). This calculation uses the following formula (*Item Discrimination* = IDsI):

$$\mathbf{IDsI} = \frac{\mathbf{T - B}}{\mathbf{N / 4}}$$

Where : **T** = The number of respondents in the top 25% scoring group
B = The number of respondents in the bottom 25% scoring group
N = the total sample (value used = 25% of sample)

The general rule of thumb is that items with a discriminatory value of +0.200 and above are acceptable. All scores on the 9-item *science knowledge* question set were above a value of 0.415 and were retained as they provided optimal discriminatory value.

RESPONSE ANALYSIS

Data in this section was analysed by running frequencies, cross-tabulations and related analysis within *SPSS* for all 9 items within the *science knowledge* question set. Data outputs for individual questions were then processed and responses to all questions were analysed for each response category. All respondents in the total sample of 3 486 provided an answer to each item within this question set.

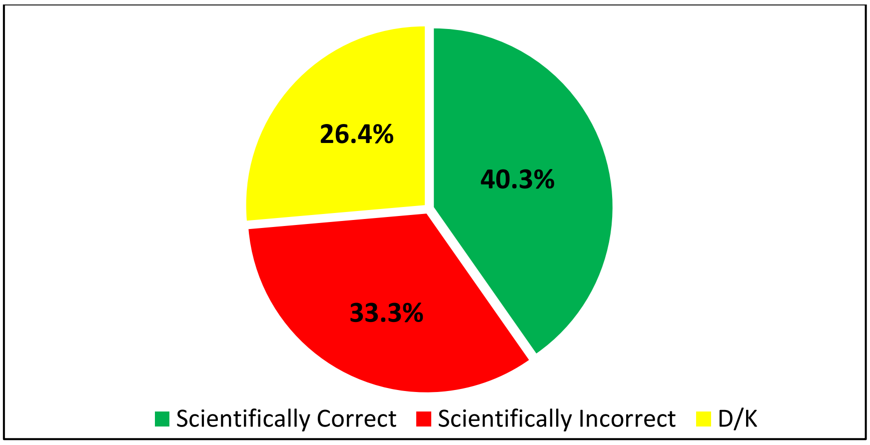


Chart A2-2: Overall result: South African *Science Knowledge* assessment (Khayabus wave 2, 2015)

The average proportion of *Scientifically Correct* answers across all the statements for the entire South African sample of 3 486 participants, was 1 404 (40.3%) while 1 162 (33.3%) provided a *Scientifically Incorrect* responses. A further 920 respondents (26.4%) made use of the *Don't Know* response option. The above general result indicates that across all science subject areas included, 40.3% of the sample was able to provide *scientifically valid* response. While this is the largest share of the response breakdown, it does offer insight into the general level of South African public scientific literacy. While it is noted that individuals that have been exposed to scientific material and media, across all subject areas would be at an advantage to those that have not had a similar level of exposure, all questions within this survey module should be answerable by those with *some or completed* high school education, which includes 76.9% of the total sample. The population demographics and issues related to social inequality however, previously discussed, are noted and taken into consideration when reviewing the above general result from this survey. The 59.7% of respondents that provided *scientifically incorrect* and *don't know* responses does highlight an interesting finding, which will be further explored by related population demographic analysis in a later section.

The removal of individual responses using the *don't know* category reveals a different picture of the South African public *science knowledge* assessment. Chat A2-3 below presents the survey data for the *science knowledge* question set, however with all *don't know* responses removed and the base proportionality calculation adjusted similarly. Among the total sample of 3 486 respondents, an average of 920 respondents elected to use the *don't know* option. The remaining 2 566 responses indicate that, 59.4% of individuals were able to provide the *scientifically correct* response, while 40.6% provided *scientifically incorrect* responses.

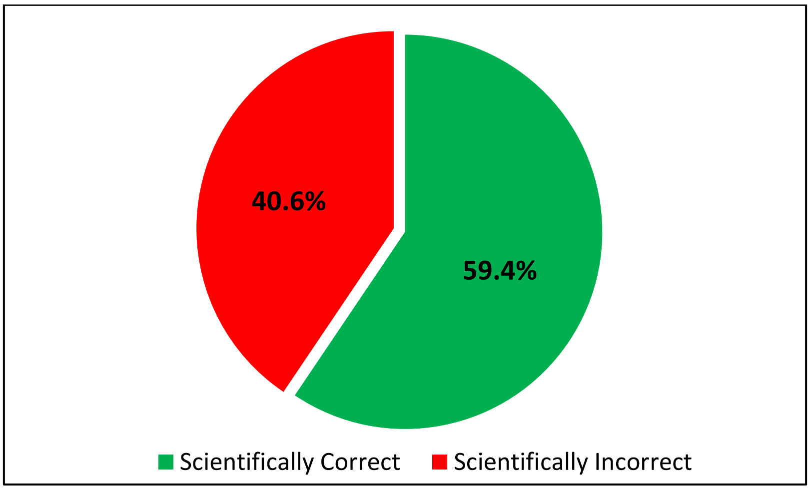


Chart A2-3: Overall result: South African *Science Knowledge* assessment (D/K removed)

Response analysis per individual respondent indicates that the majority of participants were able to correctly respond to 4 of the 9 questionnaire items. Respondents able to correctly respond to, between 3 and 5 of the 9 questionnaire items accounted for 2 037 (58.4%) of the total 3 486. At the extreme ends of the response analysis, only a single respondent was able to respond correctly to all 9 questionnaire items, while 298 (8.5%) respondents did not provide a single correct response (see chart A2-4).

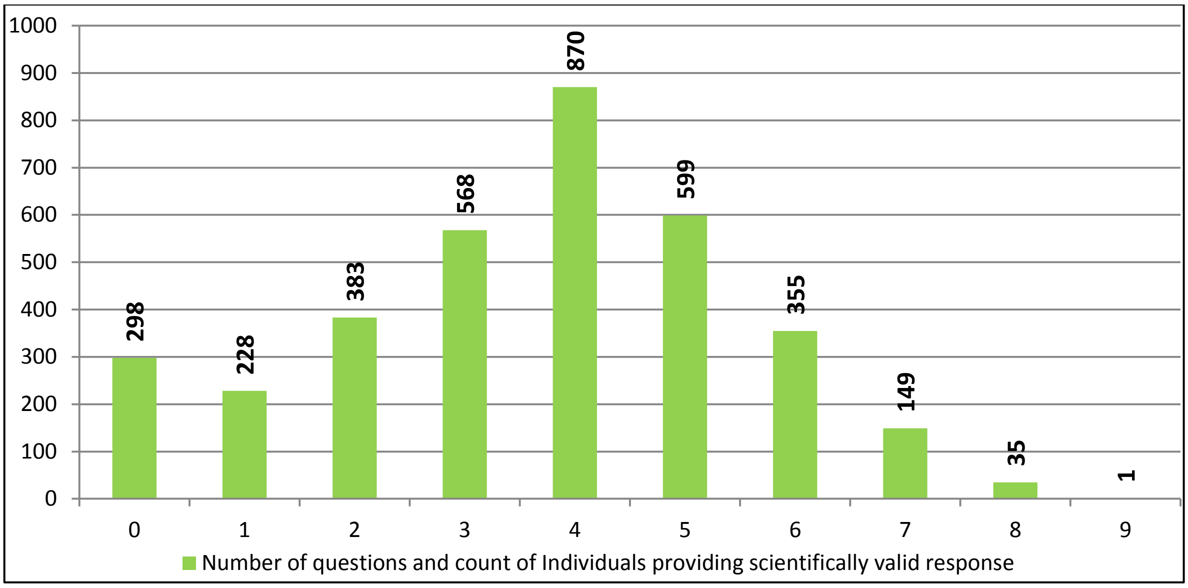


Chart A2-4: Response analysis: South African *Science Knowledge* assessment

Respondents selecting the *scientifically incorrect* and the *don't know* response options collectively account for the proportion of participants with lower levels of *scientific knowledge*. These individuals make up 59.7% of the total sample of 3 486.

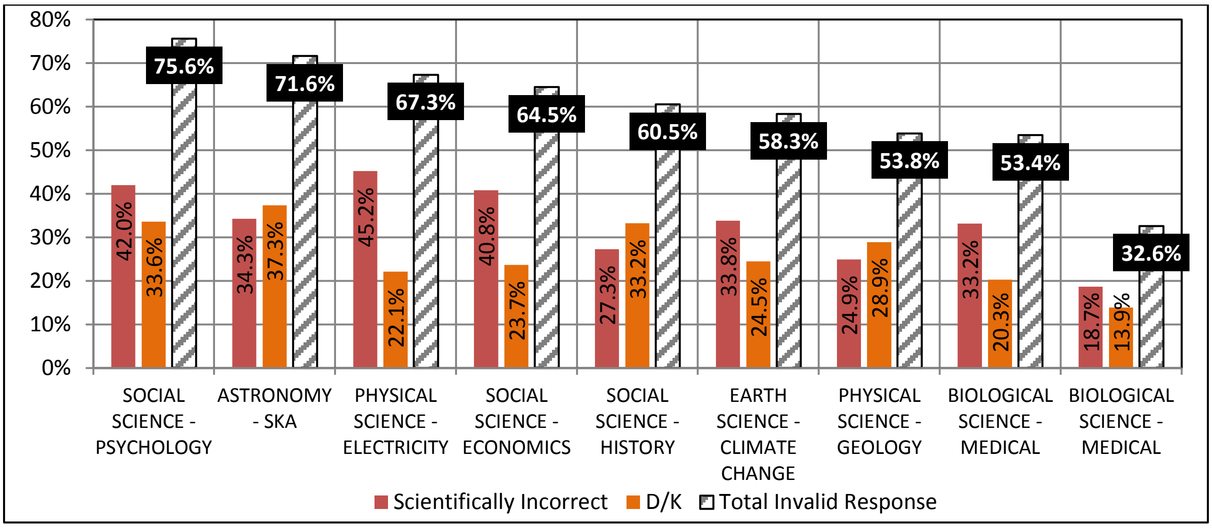


Chart A2-5: Response analysis: Scientifically invalid responses - *Science Knowledge* assessment

Among these respondents, the science subject area attracting the highest number of *scientifically incorrect* and *don't know* responses was *Social Sciences – Psychology* (75.6%) followed by *Astronomy – SKA* (71.6%). These two categories attracted 42.0% and 34.3% *scientifically incorrect* responses and 33.6% and 37.3% *Don't Know* responses, respectively. The *Physical Sciences – Electricity* (67.3%), *Social Sciences – Economics* (64.5%) and *Social Sciences – History* (60.5%) represent the next 3 categories of most frequent *scientifically invalid* response. *Physical Sciences – Geology* (53.8%) as well as the 2 *Medical Science* categories (53.4% and 32.6%) attracted the lowest proportion of *scientifically invalid* responses (see chart A2-5).

Appendix 3

Attitudes towards Science: Reliability Analyses

To adequately respond to this requirement, multiple data sources were reviewed (see chapter 3) and an extensive listing of attitudinal statements were considered prior to the finalisation of the items used in the research instrument. General attitudes toward science were measured within this research using a 4-item attitudinal scale (see chapter 4 for details). Questions were developed or adopted from various sources and following a pilot phase, the final 4-item question set was produced (see table A3-1).

	Attitudinal Statement	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	DON'T KNOW
1	Science and technology are making our lives healthier, easier and more comfortable	1	2	3	4	5	8
2	It is not important for me to know about science in my daily life	1	2	3	4	5	8
3	Thanks to science and technology, there will be more opportunities for the future generation	1	2	3	4	5	8
4	The application of science and new technology makes our way of life change too fast	1	2	3	4	5	8

Table A3-1: 4-Item attitude to science question set in Khayabus wave 2, 2015

Assessments of public attitudes to science are often *specific* to fields of science (like biotechnology or nuclear energy), but also take on a more *general* stream when considering general attitudes to science. This research focused on general attitudes to science and adopted the 4 questionnaire items used in multiple international studies as part of the final research instrument. Items 1 and Item 3 have been adopted directly from Shukla & Bauer's 2009 work, while item 2 was adapted by the author based on the findings of Bann and Schwerin (2004)[164]. The last question in the attitude section was adapted and edited from the original work of Shukla & Bauer (2009).

The questions adopted, speak directly to the 4 areas of social influence science may have on South African society (see paragraph 1 of this section). Item 1 assesses attitudes toward the *contribution* of science to the lived reality of respondents, while Item 3 looks at the role of science in *shaping a future society*. Item 2 investigates the personal *value* attached to science in daily activities, while item 4 produces an indication of perceived public *risk perception* associated with scientific advancement. The grouping of these items is deliberate, as Items 1 and 3 carry a *supportive*

[164] Though to note this item has appears in other research of similar nature, it was not used as result of those readings but instead as an item that assess the value that science presented to the respondents own life.

sentiment about science while items 2 and 4 are somewhat *critical* of the contribution of science to society. This speaks to the notion of *scientific promise* and *scientific reservation*, which will be discussed later in this chapter.

TOTAL 3486							
Attitudinal Statement	**STRONGLY AGREE**	**AGREE**	**NEITHER AGREE OR DISAGREE**	**DISAGREE**	**STRONGLY DISAGREE**	**D/K**	**N**
ITEM 1: PROMISE	1 014	1 232	670	232	121	217	3 486
ITEM 2: RESERVATION	1 011	1 340	600	200	120	215	3 486
ITEM 3: PROMISE	609	951	731	609	381	205	3 486
ITEM 4: RESERVATION	984	1 263	636	247	135	221	3 486

% TOTAL 3486							
Attitudinal Statement	**STRONGLY AGREE**	**AGREE**	**NEITHER AGREE OR DISAGREE**	**DISAGREE**	**STRONGLY DISAGREE**	**D/K**	**N**
ITEM 1: PROMISE	29.1%	35.3%	19.2%	6.7%	3.5%	6.2%	100.0%
ITEM 2: RESERVATION	29.0%	38.4%	17.2%	5.7%	3.4%	6.2%	100.0%
ITEM 3: PROMISE	17.5%	27.3%	21.0%	17.5%	10.9%	5.9%	100.0%
ITEM 4: RESERVATION	28.2%	36.2%	18.2%	7.1%	3.9%	6.3%	100.0%

Table A3-1-2: Questionnaire Response per item (Attitudes to Science)

RECODING and DATA TREATMENT

The 4 items in the attitudinal assessment question all required a single selection response from within a 5-point array of agreement options ranging from *strongly agree* to *strongly disagree* (with a neutral option). Each item row also had a *don't know* response option (see table A3-1). Valid item responses were located within one of the 5 options provided (excluding *don't know*). Where required, response categories were collapsed to create *Agree, Neutral* and *Disagree* categories, from the original 5 categories.

In preparation for additional analytic applications, 2 recoding processes were performed for these attitudinal variables. The original recoding structure was maintained while additional variables were created within this data and recoding applied to allow for the extraction and analysis within in more meaningful categories. The original coding as per the questionnaire used numerical coding 1 through 5 and adopted 8 as the code for the *don't know* response option.

During an initial recoding step, this coding structure was maintained for the positive items (item 1 and item 3) however the coding was reversed for the critical items (item 2 and item 4). This resulted in coding for items 2 and 4 as reflected in table A3-2 below. This ensured that all responses to attitudinal question are on a similar scale such that high scores reflect positive attitudes and low scores reflect negative attitudes. Here it is postulated that positive responses to positive items and negative responses to negative items reflect a general positive attitudes and visa-versa.

Reverse coding of attitude items	STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE
ORIGINAL CODING (ITEM 1 AND 3)	1	2	3	4	5
REVERSE CODING (ITEM 2 AND 4)	5	4	3	2	1

Table A3-2: Reverse coding of critical attitudinal items

These recoding categories were then collapsed, such that *Strongly Agree* and *Agree* responses became a single *Agree* category, coded as 1. *Strongly Disagree* and *Disagree* responses were similarly collapsed into a single *Disagree* category and were coded as 3. All neutral responses were coded as 2 (see below)

	Original 5 point coding				
	STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE
ORIGINAL CODING	1	2	3	4	5

	Revised 3 point coding		
	AGREE	NEUTRAL	DISAGREE
POSITIVE (ITEM 1 AND 3)	1	2	3
CRITICAL (ITEM 2 AND 4)	3	2	1

Table A3-3: Revised coding of attitudinal items

The collapsing of these categories ensured that a single scale was achieved to provide the general *direction* of respondent attitude across all 4 questionnaire items. This allowed for the 4 items within the question set to be integrated toward the development of an *attitudinal index* score for each respondent (to be discussed later). However as a consequence, an indication of the relative *strength* of these attitudes was lost within the 3-point recoding structure. As a result, and for a different analytical application, a further recoding was completed, again differentiating the positive items from the critical items in the attitudinal assessment, however this time reverting to a 5 point coding system. This ensured that the *strength* and *direction* of the respondents' original selection is maintained within the dataset under a (second) set of attitude variables. This additional coding structure adopted a 5-point structure, ranging from +1 to -1, and applied reverse coding to critical items (see table A3-4).

POSITIVE ITEMS (ITEMS 1 AND 3)

POSITIVE ITEMS (1 & 3)					
STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE	DK
1	0.5	0	-0.5	-1	8

CRITICAL ITEMS (REVERSED SCALE – ITEMS 2 AND 4)

CRITICAL ITEMS (2 & 4)					
STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE	DK
-1	-0.5	0	0.5	1	8

Table A3-4: Attitudinal items recoding structure

This revised coding structure ensured that the original strength and general direction of responses to attitudinal questions would be maintained in the analysis. The outputs from these variables would be used toward developing a measure of *attitudinal ambivalence*, to be discussed at a later point in this sub-section.

RELIABILITY OF ATTITUDES TO SCIENCE QUESTION SET

As a result of the attitudinal questions being measured on an interval scale the most suitable test of reliability was found to be the Cronbach's Alpha procedure (Tredoux and Durrheim, 2004). The procedure and background to this approach was previously discussed and will not be repeated here, beyond a brief discussion on the test output.

The SPSS outputs produced a correlation matrix for each of the 4 variables within the *Attitudes to Science* question set, presented in table A3-5 below.

		ITEM 1	ITEM 2	ITEM 3	ITEM 4
Item 1	Science and technology are making our lives healthier, easier and more comfortable	**1.000**			
Item 2	It is not important for me to know about science in my daily life	0.742	**1.000**		
Item 3	Thanks to science and technology, there will be more opportunities for the future generation	0.828	0.749	**1.000**	
Item 4	The application of science and new technology makes our way of life change too fast	0.862	0.743	0.827	**1.000**

Table A3-6: Reliability Analysis Inter-Item Correlation matrix: *Attitudes to Science* question set in Khayabus wave 2, 2015

Everet (2002) and Field (2005) have proposed a threshold score of 0.300 as indicative of items that should be excluded as a result of poor inter-item correlation. All inter-item correlation values presented in table A3-6 were found to be above the threshold value proposed and thus were retained within the attitudinal question set.

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.939	0.938	4

Table A3-7: Reliability statistics: *Attitudes to Science* question set in Khayabus wave 2, 2015

The reliability statistics for the 4-item attitudes to science question set were computed and indicated a high degree of internal consistency (Cronbach's Alpha: 0.939). Examining the results of the Item-Total statistics (table A3-7) it is noted that within the column *Corrected Item-Total Correlation*, all items achieved high correlations, ranging between 0.788 and 0.881. This result confirms the high degree of internal consistency between the items in this question set. The column headed *Cronbach's Alpha if Item Deleted* provides an indication of the impact each item has on the overall Cronbach's Alpha score (see table A3-8) should that item be deleted. All values within the scale are between 0.91 and 0.94. While item 2 was marginally higher than the reported Cronbach's Alpha reported earlier (0.939), this was found to not change the overall reliability of the question set in any meaningful way (0.001) and thus the item was retained.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Science and technology are making our lives healthier, easier and more comfortable	5.82	22.329	**0.881**	0.792	**0.911**
It is not important for me to know about science in my daily life	5.46	23.871	**0.788**	0.622	**0.940**
Thanks to science and technology, there will be more opportunities for the future generation	5.87	22.545	**0.867**	0.755	**0.915**
The application of science and new technology makes our way of life change too fast	5.81	22.193	**0.880**	0.791	**0.911**

Table A3-8: Reliability Analysis Item Total statistics: *Attitudes to Science* question set in Khayabus wave 2, 2015

According to Tavakol and Dennick (2011) an acceptable level of Cronbach's Alpha should be between the range of 0.70 and 0.95. The above results therefore indicate that the 4-item *Attitudes to Science* question set retains a high level of internal consistency and therefore provides a reliable measure of *attitudes to science* within this questionnaire, achieving a Cronbach's Alpha of 0.939.

RESPONSE ANALYSIS

Overall response to the *attitudes to science* question set is presented in table A3-9. All 3 486 respondents within the sample responded to each of the 4 items within the question set.

Attitudinal Statement	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	D/K	N	VALID N	% valid
Science and technology are making our lives healthier, easier and more comfortable	1014	1232	670	232	121	217	3486	3269	93.8%
It is not important for me to know about science in my daily life	609	951	731	609	381	205	3486	3281	94.1%
Thanks to science and technology, there will be more opportunities for the future generation	1011	1340	600	200	120	215	3486	3271	93.8%
The application of science and new technology makes our way of life change too fast	984	1263	636	247	135	221	3486	3265	93.7%

Table A3-9: Overall result: South African Attitudes to Science assessment (Khayabus wave 2, 2015)

However an average of 215 individuals selected the *don't know* option across all 4 items, which were considered invalid, thus yielding valid item response rates between 93.7 and 94.1% for items within this question set (see table A3-9). The responses were recoded and response categories were collapsed from 5 categories to 3 categories (as discussed above), the overall results are now presented within this 3 category format.

Appendix 4

Interest in Science: Reliability Analyses

The next section of this chapter outlines the development of the questionnaire items assessing interest in science, data treatment procedures, reliability as well as general results to the *interest in science* question set within this survey module.

QUESTIONNAIRE ITEMS

During the development of the survey instrument, due consideration was applied toward integrating the input material for the measurement of the public understanding of science elements for *knowledge*, *interest* as well as *informedness*. This was done in order to ensure that each of these elements considers and relates to the same areas of scientific knowledge as well as simultaneously ensuring the data across each of the three measurement areas are comparable.

Interest in science was measured using a 3-level interest scale as well as a *don't know* response option. These interest levels ranged from *Very Interested, Moderately Interested* to *No Interest*. This 3-level *interest in science* scale was used to assess interest within 7 scientific disciplines that have a direct relation to the items within the *science knowledge assessment* question set (see chapter 4).

The 7 items included in the interest in science question set are presented in table A4-1 below. In addition to the commonalities of subject areas with the *science knowledge assessment* items, each of the *interest in science* items reflects a critical contribution area for science in the current South African *National System of Innovation*.

	Interest Area	VERY INTERESTED	MODERATELY INTERESTED	NO INTEREST	DON'T KNOW
1	Medical Science	1	2	3	8
2	Climate Change	1	2	3	8
3	Technology and the Internet	1	2	3	8
4	Politics	1	2	3	8
5	Economics	1	2	3	8
6	Astronomy	1	2	3	8
7	Energy	1	2	3	8

Table A4-1: 7-Item *Interest in Science* question set in Khayabus wave 2, 2015

Moreover each of these 7 areas has a critical impact on current and planned activities that are projected to contribute in significant ways to the future developmental agenda in South Africa. It remains important to note that during the fieldwork for this research, data collectors were instructed to not read out the *don't know* response option, but simply record respondent feedback should they indicate this verbally.

Questionnaire response per each of the seven (7) items is presented in Table A4-1-2 below:

	VERY INTERESTED	MODERATELY INTERESTED	NO INTEREST	DON'T KNOW	N	VALID N
Medical Science	807	1035	1422	222	3486	3264
Climate Change	782	1172	1310	222	3486	3264
Technology and the Internet	1030	1096	1168	192	3486	3294
Politics	588	1144	1599	155	3486	3331
Economics	798	1153	1343	192	3486	3294
Astronomy	416	846	1887	337	3486	3149
Energy	747	1095	1399	245	3486	3241

	VERY INTERESTED	MODERATELY INTERESTED	NO INTEREST	DON'T KNOW	N	VALID N
Medical Science	23.1%	29.7%	40.8%	6.4%	100.0%	52.8%
Climate Change	22.4%	33.6%	37.6%	6.4%	100.0%	56.1%
Technology and the Internet	29.5%	31.4%	33.5%	5.5%	100.0%	61.0%
Politics	16.9%	32.8%	45.9%	4.4%	100.0%	49.7%
Economics	22.9%	33.1%	38.5%	5.5%	100.0%	56.0%
Astronomy	11.9%	24.3%	54.1%	9.7%	100.0%	36.2%
Energy	21.4%	31.4%	40.1%	7.0%	100.0%	52.8%

Table A4-1-2: Questionnaire Response per item (Interest in Science*)*

RECODING and DATA TREATMENT

The interest in science question set required little data treatment and recoding within the data analysis phase of this research. The 3-level interest in science response categories were adopted within the data set and are reported within the following sub-sections.

A minor recoding procedure was performed wherein response to each of the 7 questions were classified into one of three new categories that was to be used during the development of an index of *interest in science*. Within this recoding procedure IBM SPSS 24.0 was used to perform recoding and the creation of a new variable. The result of this recoding procedure reclassified all *don't know* responses as *missing*; *no interest* responses as 0; *moderate interest* as 1 and *high interest* responses as 2. These new values were then adopted into the development of the *index of interest in science*.

RELIABILITY OF INTEREST IN SCIENCE QUESTION SET

An assessment of the reliability of the interest in science question set was performed adopting the Cronbach's Alpha procedures describes previously.

The SPSS output produced a correlation matrix for each of the 7 variables within the *Interest in Science* question set and is presented in table A4-5 below.

INTEREST in SCIENCE	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7
Medical Science	**1.000**						
Climate Change	0.775	**1.000**					
Technology and the Internet	0.736	0.709	**1.000**				
Politics	0.626	0.622	0.646	**1.000**			
Economics	0.744	0.717	0.707	0.686	**1.000**		
Astronomy	0.657	0.614	0.591	0.516	0.628	**1.000**	
Energy	0.797	0.744	0.684	0.617	0.733	0.688	**1.000**

Table A4-5: Reliability Analysis Inter-Item Correlation matrix: 7-Item *Interest in Science* question set

The previously discussed threshold measure as proposed by Everet (2002) and Field (2005) have similarly been applied to the analysis of the inter-item correlation matrix within the interest in science question set. Each of the 7 items within the question set produced high inter-item correlations and was found to relate well to each other item within the question set.

The reliability statistic produced within the SPSS output indicated a high degree of internal consistency (Cronbach's Alpha: 0.936) among the 7 questionnaire items and is presented in table A4-5 below:

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.936	0.936	7

Table A4-5: Reliability statistics: *interest in Science* question set in Khayabus wave 2, 2015

Results of the Item-Total statistics (table A4-6) within the *Corrected Item-Total Correlation* column demonstrates high item total correlation values ranging between 0.712 and 0.855. This further confirms the previously discussed high level of internal consistency among the 7 questionnaire items. All values within the column headed *Cronbach's Alpha if Item Deleted* is within the range of 0.920 and 0.934, below the level of the Cronbach's Alpha (0.936) reported earlier. This indicates that there would be no significant change to the reliability measure should any of the items be deleted.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Medical Science	15.56	65.393	**0.855**	0.749	**0.920**
Climate Change	15.58	66.264	**0.818**	0.684	**0.923**
Technology and the Internet	15.75	67.438	**0.792**	0.641	**0.926**
Politics	15.56	71.767	**0.712**	0.537	**0.933**
Economics	15.63	67.252	**0.824**	0.687	**0.923**
Astronomy	15.11	66.665	**0.712**	0.526	**0.934**
Energy	15.51	65.063	**0.839**	0.722	**0.921**

Table A4-6: Reliability Analysis Item Total statistics: *Interest in Science* question set in Khayabus wave 2, 2015

These results thus indicate that the 7-item *Interest in Science* question set retains a high level of internal consistency and therefore provides a reliable measure of respondent *interest in science* within this study.

RESPONSE ANALYSIS

Across all 7 interest areas related to science, respondent reported interest in science is presented in chart A4-7. All 3 486 respondents within the valid sample provided a response to each of the 7 items within the interest in science question set (see table A4-7). Regardless of this response, an average of 224 respondents at each of the 7 items selected the *don't know* response option, and these responses were considered invalid. The average valid response to the interest in science question set is therefore 3 262 representing 93.6% of the total sample.

Interest Area	**Very Interested**	**Moderately Interested**	**No Interest**	**D/K**	**N**	**VALID N**	**VALID N %**
Medical Science	807	1035	1422	**222**	3486	3264	**93.6%**
Climate Change	782	1172	1310	**222**	3486	3264	**93.6%**
Technology and the Internet	1030	1096	1168	**192**	3486	3294	**94.5%**
Politics	588	1144	1599	**155**	3486	3331	**95.6%**
Economics	798	1153	1343	**192**	3486	3294	**94.5%**
Astronomy	416	846	1887	**337**	3486	3149	**90.3%**
Energy	747	1095	1399	**245**	3486	3241	**93.0%**

Table A4-7: Overall results: South African Interest in Science assessment (Khayabus wave 2, 2015)

Response for all 7 questionnaire items represents the overall level of interest within the fields of science included. Among the 3 262 respondents, 22.6% indicated that they were *very interested* while 33.0% *of participants* indicated that they were *moderately interested* any of the 7 scientific interest areas. Within the total response to this question set, 44.4% of the total valid response indicated that they have *no interest* in any of the 7 areas of science (see chart A4-8).

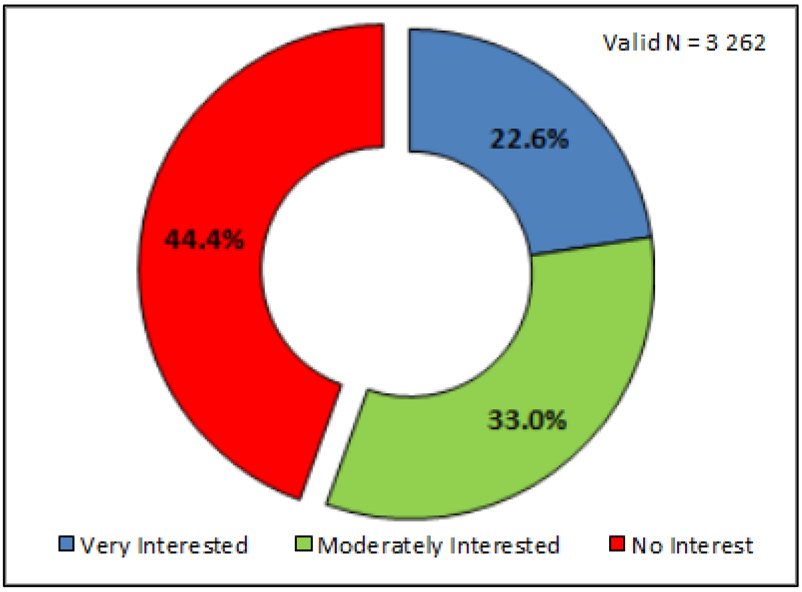


Chart A4-8: Overall result: South African Interest in Science assessment (Khayabus wave 2, 2015)

These overall response patterns did vary within each item and within the various demographic classification groupings which will be discussed in greater detail in the following sections. Overall response to the 7 items within the question set will be initially presented by examining response frequencies and South Africans' interest in science at an aggregate level. This will then be followed by a closer examination within the demographic classifications discussed in earlier sections.

Appendix 5

Level of Informedness about Science: Reliability Analyses

The next sub section presents the development, processing and results of the data related to the level of *informedness in science* within the South African population. As the specific questionnaire items, coding procedures and data treatment did not deviate appreciably from those mentioned within the preceding section, these will be concisely presented in the next section, prior to the presentation of the general results to the *informedness in science* question set within this research study.

QUESTIONNAIRE ITEMS

The noted relationship between *scientific knowledge*, *scientific interest* and *scientific informedness* continued to inform the development and design of the questionnaire items within the measurement of *scientific informedness*.

As with the Interest *in science* items, *informedness in science* was measured using a 3-level informedness scale as well as a *don't know* response option. This scale however ranged from *Very well informed, moderately well informed* to *not well informed*. This 3-level *informedness in science* scale was used to assess interest within the same 7 scientific disciplines that have been presented within the *interest in science* question set (see previous section and greater detail in chapter 4).

Each of the *informedness in science* items are the same as those included within the *interest in science* question set to ensure comparability in the data with regard to the interrelation between *interest* and *information seeking* outcomes. While the response scale differs from the interest items, overall item text and order remains unchanged (see table A5-1 below).

	Interest Area	VERY WELL INFORMED	MODERATELY WELL INFORMED	NOT WELL INFORMED	DON'T KNOW
1	Medical Science	1	2	3	8
2	Climate Change	1	2	3	8
3	Technology and the Internet	1	2	3	8
4	Politics	1	2	3	8
5	Economics	1	2	3	8
6	Astronomy	1	2	3	8
7	Energy	1	2	3	8

Table A5-1: 7-Item *Informedness in Science* question set in Khayabus wave 2, 2015

As with the interest items during the fieldwork for this research, data collectors were trained to not read out the *don't know* response option, but simply record respondent feedback should they indicate this verbally.

	VERY WELL INFORMED	MODERATELY WELL INFORMED	NOT WELL INFORMED	DON'T KNOW	N %	VALID N %
Medical Science	13.5%	26.4%	52.8%	7.4%	100%	92.6%
Climate Change	12.8%	30.8%	49.6%	6.8%	100%	93.2%
Technology and the Internet	18.8%	31.1%	43.3%	6.8%	100%	93.2%
Politics	14.2%	34.6%	45.0%	6.3%	100%	93.7%
Economics	14.8%	29.2%	48.9%	7.1%	100%	92.9%
Astronomy	8.5%	19.1%	61.7%	10.7%	100%	89.3%
Energy	13.4%	26.3%	52.3%	8.1%	100%	91.9%

Table A5-1-2: Questionnaire Response per item (Informedness about Science)

RECODING and DATA TREATMENT

The informedness in science question set adopted the same data treatment and minor recoding procedures presented earlier in this chapter. As a result those processes will not be repeated here, except where variations to the presented procedures occurred. The 3-level *informedness in science* response categories were adopted within the data set and are reported within the following sub-sections. Where required, all *Very Well Informed* and *Moderately Well Informed* responses were combined into a single *SUM Informed* category, for purposes of clarity, ease of analysis and data presentation.

A minor recoding procedure was performed as with the *interest in science* items wherein the all *don't know* responses were recoded as *missing*; *not well informed* responses as 1; *moderately well informed* 2 and *very well informed* responses as 3.

RELIABILITY OF INFORMEDNESS IN SCIENCE QUESTION SET

Similar to the preceding section, an assessment of the reliability of the *informedness in science* question set was performed adopting the Cronbach's Alpha procedures previously described.

The correlation matrix for each of the 7 variables within the *informedness in Science* question set was produced and demonstrated an appropriately high inter-item correlation among each of the items, above the stated threshold value (see table A5-2).

Informedness Area	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7
Medical Science	**1.000**						
Climate Change	0.824	**1.000**					
Technology and the Internet	0.752	0.764	**1.000**				
Politics	0.657	0.685	0.661	**1.000**			
Economics	0.787	0.786	0.733	0.714	**1.000**		
Astronomy	0.727	0.697	0.657	0.564	0.681	**1.000**	
Energy	0.843	0.800	0.718	0.658	0.779	0.771	**1.000**

Table A5-2: Reliability Analysis Inter-Item Correlation matrix: 7-Item *informedness in Science* question set

The reliability statistic (Cronbach's Alpha: 0.949) indicated a high degree of internal consistency among the 7 questionnaire items within the informedness in science question set (see table A5-3). This indicates that all items are closely associated with each other thereby providing evidence of overall reliability within the question set.

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.949	**0.949**	**7**

Table A5-3: Reliability statistics: *informedness in Science* question set in Khayabus wave 2, 2015

Table A5-4 presents the *Item-Total Statistics* output from SPSS, where in the *item-total correlation* values indicate a high degree of correlation among the 7 questionnaire items. All indications within the *Cronbach's Alpha if Item Deleted* column is below the value of the Cronbach's Alpha in table 5.49 (0.949) and thus indicate no appreciable increase in reliability should any of the items be removed.

Informedness Area	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Medical Science	16.92	72.972	**0.878**	0.794	**0.936**
Climate Change	16.98	73.941	**0.870**	0.768	**0.937**
Technology and the Internet	17.11	74.505	**0.810**	0.666	**0.942**
Politics	17.08	77.558	**0.735**	0.568	**0.948**
Economics	16.99	73.712	**0.852**	0.735	**0.938**
Astronomy	16.58	73.165	**0.771**	0.629	**0.946**
Energy	16.89	72.213	**0.875**	0.791	**0.936**

Table A5-4: Reliability Analysis Item Total statistics: *informedness in Science* question set in Khayabus wave 2, 2015

These results thus indicate that the 7-item *informedness in science* question set retains a high level of internal consistency and therefore provides a reliable measure of respondent *informedness* with respect to the 7 questionnaire items adopted in this study.

RESPONSE ANALYSIS

All 3 486 respondents within the sample provided a response to each of the 7 items within the *informedness in science* question set. With this total response, and average of 264 respondents selected the *don't know* response option, considered invalid, thus yielding a valid response rate of 92.6% within this item (see table A5-5).

Informedness Area	VERY WELL INFORMED	MODERATELY WELL INFORMED	NOT WELL INFORMED	DON'T KNOW	N	VALID N	VALID N %
Medical Science	469	919	1841	257	3486	**3229**	92.6%
Climate Change	447	1074	1729	236	3486	**3250**	93.2%
Technology and the Internet	656	1085	1508	237	3486	**3249**	93.2%
Politics	494	1205	1569	218	3486	**3268**	93.7%
Economics	516	1018	1706	246	3486	**3240**	92.9%
Astronomy	295	667	2150	374	3486	**3112**	89.3%
Energy	467	916	1822	281	3486	**3205**	91.9%

Table A5-5: Overall results: South African informedness in Science assessment (Khayabus wave 2, 2015)

Among the 3 486 individuals responding to this question set, across the 7 *informedness in science* items, an average of 13.7% indicated being *very well informed*; 28.2% indicated that they are *moderately well informed* while 50.5% report being *not well informed*. Among the total response, an average of 7.6% indicated a *don't know* response. The total valid response proportions are presented in chart A5-6.

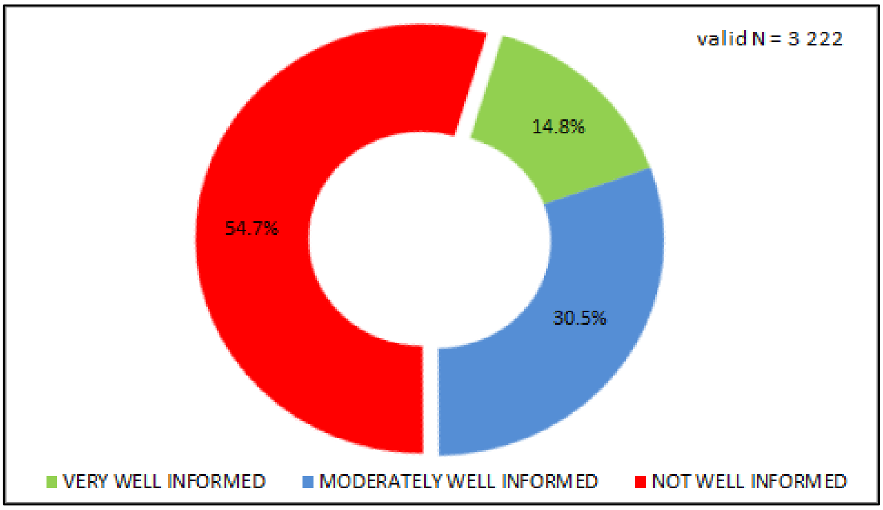


Chart A5-6: Overall result: South African informedness in science assessment (Khayabus wave 2, 2015)

Within the valid response, 14.8 % of respondents indicate being *very well informed* while 30.5% of respondents indicated being *moderately well informed*. The largest share of respondents, across the 7 items reported being *not well informed* (54.7%).

Within the sample, overall response patterns did vary among the various demographic classification groupings. Response patterns will initially be addressed at the overall national level followed by a more detailed examination of these results within each demographic classification.

Appendix 6

Sources of information about science: Reliability Analyses

Within this study an assessment was operationalised toward gaining an understanding of the main sources of science information among the South African public. This subsection describes the questionnaire items, data treatment, and reliability assessment as well as presenting the overall results of the evaluation of the main sources of scientific information for South African public.

QUESTIONNAIRE ITEMS

An assessment of the main sources of scientific information among the South African public was operationalised adopting 11 information sources, from within a multitude of media, public and private information streams. While media monitoring information does exist for the South African population via noted market research surveys such as the *All Media and Products Survey* (South African Audience Research Foundation - AMPS), relating it back to specifically to areas of science remains impossible with AMPS data (see chapter 4).

Within the 11 information source items respondents were asked to indicate the frequency of actively encountering science information using a 3-point frequency scale. The scale ranged from *Most Frequently*, *Occasionally* to *Least Frequently*, with an additional *Don't Know* option provided, but as before not read to respondents. The 11 items used within this assessment of sources of scientific information ranged from Broadcast (*Television and Radio*); Print (*Newspapers, Books and Magazines*), Online (*News websites, Social Media, Institutional websites*) as well as Human information sources (*Other people* and *Government*). These sources cover aspects related to traditional media, such as print and broadcast as well as new media sources within digital online platforms.

Within this question set, the media format is of most interest in this question as it differentiates the various information channels to best understand sources of scientific information, beyond technological penetration factors. The 11 information source categories as well as the response scale is presented in table A6-1 below.

	Information Source	MOST FREQUENTLY	OCCASIONALLY	LEAST FREQUENTLY	DON'T KNOW
1	Satellite Pay Television such as DSTV or Star Sat	1	2	3	8
2	Free-to-Air Television such as SABC or ETV	1	2	3	8
3	Radio	1	2	3	8
4	Newspapers	1	2	3	8
5	News Websites	1	2	3	8
6	Institutional Websites such as University or Research Labs	1	2	3	8
7	Government Announcements	1	2	3	8
8	Blogs	1	2	3	8
9	Social media such as Facebook or Twitter	1	2	3	8
10	Other people such as Family, Friends, or Colleagues	1	2	3	8
11	Books / Magazines	1	2	3	8

Table A6-1: 11-Item *Sources of Scientific Information* question set in Khayabus wave 2, 2015

Important advances within the above question set are the disaggregation of the broadcast channels to include both digital pay services (DSTV / Star Sat) and terrestrial TV services (SABC). Similarly online information sources have been classified into distinct categories of *social media*, *blogs*, *news* and *institutional* websites. These distinctions allow for greater disaggregation within the responses as well as providing greater accuracy within these important sources of information and learning.

RECODING and DATA TREATMENT

Within items response analysis minimal recoding was applied to the data and reporting is largely within the questionnaire categories discussed earlier. Where required the 2 highest frequency categories were combined to produce a SUM frequency response, however this did not require any data recoding.

New variables were created for items within this question set where all responses were reverse coded. The questionnaire categories applied a coding wherein a *Most Frequently* response received a code of 1, while a *Least Frequently* response received a code of 3. To ensure that the higher information source access frequency related to the higher coding value, the questionnaire codes were reversed. The revised coding structure ensured that a *Most Frequently* response received a code of 3, *occasionally* was coded as 2; while a *Least Frequently* response received a code of 1. These recoded values were used as scores to allow for the application of the responses within the development of an *index of information immersion*.

RELIABILITY OF INFORMATION SOURCES IN SCIENCE QUESTION SET

The Cronbach's Alpha was employed in assessing the reliability of this question set, as within the preceding sections. While in questions of this nature it is not entirely required, it will be briefly presented below for completeness.

All 11 items within the question set obtained sufficiently high inter-item correlation values (see table A6-2). While some low inter-item correlations are noted within the 0.400 range, this was not entirely unexpected and remains above the stated threshold value (0.300).

	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10	ITEM 11
Satellite Pay Television such as DSTV or Star Sat	1.000										
Free-to-Air Television such as SABC or ETV	0.504	1.000									
Radio	0.449	0.655	1.000								
Newspapers	0.562	0.576	0.650	1.000							
News Websites	0.699	0.470	0.445	0.546	1.000						
Institutional Websites such as University or Research Labs	0.692	0.473	0.436	0.530	0.840	1.000					
Government Announcements	0.656	0.536	0.495	0.578	0.724	0.770	1.000				
Blogs	0.671	0.462	0.404	0.506	0.791	0.815	0.753	1.000			
Social media such as Facebook or Twitter	0.687	0.480	0.430	0.541	0.752	0.745	0.695	0.784	1.000		
'Other people such as Family, Friends, or Colleagues '	0.600	0.576	0.530	0.580	0.582	0.579	0.622	0.582	0.667	1.000	
Books / Magazines	0.689	0.570	0.555	0.639	0.664	0.673	0.661	0.650	0.689	0.710	1.000

Table A6-2: Reliability Analysis Inter-Item Correlation matrix: 11-Item *Science Information sources* question set

The reliability statistic for the Cronbach's Alpha was computed to be 0.946 and indicates a high degree of internal consistency among the 11 questionnaire items (see table A6-3).

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.946	**0.945**	**11**

Table A6-3: Reliability statistics: *Science Information Sources* question set in Khayabus wave 2, 2015

The *Item-Total Statistics* are presented in table A6-4 wherein the *item-total correlation* values indicate a high degree of correlation among the 11 questionnaire items.

INFORMATION SOURCE	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Satellite Pay Television such as DSTV or Star Sat	37.87	415.916	**0.774**	0.619	**0.940**
Free-to-Air Television such as SABC or ETV	38.72	437.446	**0.643**	0.530	**0.945**
Radio	39.00	445.841	**0.610**	0.552	**0.946**
Newspapers	38.61	434.763	**0.699**	0.569	**0.943**
News Websites	37.31	413.332	**0.818**	0.764	**0.939**
Institutional Websites such as University or Research Labs	37.21	413.090	**0.824**	0.792	**0.938**
Government Announcements	37.59	415.832	**0.812**	0.691	**0.939**
Blogs	37.16	414.998	**0.806**	0.762	**0.939**
Social media such as Facebook or Twitter	37.58	412.166	**0.812**	0.720	**0.939**
Other people such as Family, Friends, or Colleagues	38.39	424.616	**0.745**	0.608	**0.942**
Books / Magazines	38.01	418.091	**0.810**	0.679	**0.939**

Table A6-4: Reliability Analysis Item Total statistics: *Science Information Sources* question set in Khayabus wave 2, 2015

All indications within the *Cronbach's Alpha if Item Deleted* column is below or equal to the value of the Cronbach's Alpha (0.946) and thus indicate no appreciable increase in reliability should any of the items be removed.

RESPONSE ANALYSIS

A response to each of the 11 items was realised from all 3 486 respondents within the sample. Within this response, an average of 923 respondents (across 11 items) selected a *don't know* response yielding a valid response from 2 563 respondents. A large proportion of the sample selected the *don't know* option, influencing the final response rate for this question. As a result, this question realised a 73.5% valid response from within the sample. Across all the items in this question set, 16.7% of respondents reported they *most frequently* receive science information from one of the sources listed, while 19.5% reported an *occasionally* response. The largest proportion of response was within the *least frequently* category (37.3%) while 26.5% of respondents provided a *don't know* response (see table A6-5).

INFORMATION SOURCE	Most Frequently	Occasionally	Least Frequently	D/K	N	VALID N	VALID N %
Satellite Pay Television (DSTV, TopTv)	660	592	1 243	991	3 486	2 495	71.6%
Free-to-Air Television (SABC / E-Tv)	1 084	785	1 007	610	3 486	2 876	82.5%
Radio	1 190	899	920	477	3 486	3 009	86.3%
Newspapers	797	940	1 150	599	3 486	2 887	82.8%
News Websites	255	499	1 532	1 200	3 486	2 286	65.6%
Institutional Websites (University / Research Lab)	221	428	1 594	1 243	3 486	2 243	64.3%
Government Announcements	282	654	1 499	1 051	3 486	2 435	69.9%
Blogs	182	443	1 591	1 270	3 486	2 216	63.6%
Social media (Facebook, Twitter)	451	577	1 350	1 108	3 486	2 378	68.2%
Other people (Family, Friends, Colleagues)	810	839	1 098	739	3 486	2 747	78.8%
Books / Magazines	453	838	1 333	862	3 486	2 624	75.3%

Table A6-5: Response Analysis: South African information sources on science assessment (Khayabus wave 2, 2015)

An important consideration within the proportion of *don't* know response option selections is evident under many of the internet based information sources. The items for *news websites, institutional websites, blogs and social media* attracted a significantly larger proportion of these responses. Similarly, *government announcements* also attracted more than 1 000 responses within the *don't know* response option.

Appendix 7

Science Engagement: Reliability Analyses

Toward addressing this lack of data, the following section describes the operationalisation of a *measure of attendance at science engagement activities* among the general South African public. This subsection describes the questionnaire items, data treatment, and reliability assessment as well as presenting the overall results of the evaluation of *attendance at science engagement activities* for South African public.

QUESTIONNAIRE ITEMS

The science engagement question set comprised a selection list of 5 items that represents various locations the general public would encounter a focused concentration of science information. Beyond the exposure to new information, the hallmark of the 5 items listed is that these locations exist within a context of dialogue, wherein the public may engage with scientific concepts and the people that are involved in this critical area of work.

	Science Engagement Activities	YES	NO	DON'T KNOW
1	Public Library	1	2	8
2	Zoo or Aquarium	1	2	8
3	Museum (any)	1	2	8
4	Science Centre, Technology exhibition	1	2	8
5	Science Café, Festival or similar Public Event	1	2	8

Table A7-1: 5-item science engagement question set in Khayabus wave 2, 2015

The items adopted in the questionnaire represent the key areas that members of the general public may engage with experts within their respective fields and encounter new scientific ideas. These areas include visits to and attending events at: *public libraries*; *zoo or aquariums*; *museums*; *science centres / technology exhibitions* as well as *science cafés, festivals or similar public events* (see table A7-1). Within the 5 item selection list, respondents were asked to indicate if they had *visited* one or more of the listed locations within the preceding 12 month period, by indicating a *Yes* or *No* response using a 3-point response scale[165].

[165] The 3rd point was a *don't know* response option

RECODING and DATA TREATMENT

The data requested within this item was used within the questionnaire categories toward understanding South African science engagement behaviours within the given reference period. All responses within the *don't know* response were considered invalid.

Within the development of an index, the response within this item was considered by the *count of science engagement activities attended* toward the development of an index of *science engagement*.

RELIABILITY OF SCIENCE ENGAGEMENT ACTIVITIES QUESTION SET

Toward assessing the reliability and internal consistence of the 5 items within the science engagement question, the Cronbach's Alpha procedure was employed as within previous question sets.

	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5
Public Library	**1.000**				
Zoo or Aquarium	0.759	**1.000**			
Museum (any)	0.765	0.799	**1.000**		
Science Centre, Technology exhibition	0.766	0.812	0.769	**1.000**	
Science Café, Festival or similar Public Event	0.706	0.761	0.733	0.828	**1.000**

Table A7-2: Reliability Analysis Inter-Item Correlation matrix: 5-Item *Science Engagement* question set

All items within the question set obtained sufficiently high inter-item correlation values (see table A7-2). As before the threshold of 0.300 recommended by Everet (2002) and Field (2005) has been adopted toward making an assessment within the inter-item correlation values achieved.

The Cronbach's Alpha value of 0.943 indicates a generally high degree of internal consistence among the 5 items in this question set. The reliability statistic produced within SPSS is presented in table A7-3.

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.943	**0.944**	**5**

Table A7-3: Reliability Statistics: 5-Item *Science Engagement* question set

Within the table of *Item-Total statistics* (table A7-4) it is noted that under the column *Corrected Item-Total Correlation*, all items achieved high correlations, ranging between 0.0.818 and 0.880. This result confirms the high degree of internal consistency between the items in this question set. The column headed *Cronbach's Alpha if Item Deleted* provides an indication of the impact each item has on the overall Cronbach's Alpha score should that item be deleted. All values within the scale are between 0.927 and 0.934 and as a result all items were retained within the question set.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	**Corrected Item-Total Correlation**	Squared Multiple Correlation	**Cronbach's Alpha if Item Deleted**
Public Library	8.63	20.822	**0.818**	0.678	**0.935**
Zoo or Aquarium	8.55	20.247	**0.864**	0.751	**0.927**
Museum (any)	8.53	20.750	**0.842**	0.718	**0.931**
Science Centre, Technology exhibition	8.48	20.087	**0.880**	0.786	**0.924**
Science Café, Festival or similar Public Event	8.45	20.219	**0.829**	0.718	**0.934**

Table A7-4: Reliability Analysis Item Total statistics: *Science engagement* question set in Khayabus wave 2, 2015

The guideline measure for reliability proposed by Tavakol and Dennick (2011) indicates that an acceptable level for the Cronbach's Alpha should be between 0.70 and 0.95. The above result therefore conforms to this guideline, with the Cronbach's Alpha value of 0.943. This further indicates that the 5-item *Science Engagement* question set retains a high degree of internal consistency and therefore provides a reliable measure within this questionnaire.

RESPONSE ANALYSIS

Responses were achieved from all 3 486 respondents within the sample. As noted earlier, responses within the *don't know* response option were considered invalid and as a result an average of 141 responses across the 5-item question set fell into this response category.

SCIENCE ENGAGEMENT ACTIVITIES	**YES**	**NO**	**D/K**	**N**	**VALID N**	**VALID N %**
Public Library	664	2695	127	3486	3359	96.4%
Zoo or Aquarium	438	2909	139	3486	3347	96.0%
Museum (any)	353	3000	133	3486	3353	96.2%
Science Centre, Technology exhibition	241	3098	147	3486	3339	95.8%
Science Café, Festival or similar Public Event	228	3100	158	3486	3328	95.5%

Table A7-5: Response Analysis: Science engagement activities assessment (Khayabus wave 2, 2015)

Total valid response was achieved from 3 345 respondents. This yielded an average valid response rate of 96.0%, however this did vary for individual questionnaire items (see table A7-5).

Appendix 8

FIELDWORK INSTRUMENT

NATIONAL

SECTION X –CREST SCIENCE VALUE – KHAYABUS WAVE2 2015

- ASK MALES AND FEMALES -

► INTRODUCTION: **Now let's change the subject. The idea behind the following set of questions is to gather a better understanding of how the many different South African populations encounter, appreciate and use knowledge of science in daily situations.**

The following questions are not designed to trick you in any way – so trust your first answer, it's probably correct.

Section A: Scientific Knowledge:

QX1 ASK ALL

SHOWCARD X1

OMO PER STATEMENT

ROTATE ORDER OF STATEMENTS

The following quiz-like questions are designed to measure science knowledge. The subjects cover everyday examples of science and have a single TRUE or FALSE answer.

Please indicate if the following statements are True or False…

READ OUT STATEMENTS AND REPEAT IF NECESSARY

		TRUE	FALSE	DON'T KNOW (DNRO)
1.	In the majority of cases, HIV causes AIDS in humans	-1	-2	-8
2.	Lightning never strikes the same place twice	-1	-2	-8
3.	South Africa was the first nation in the world to voluntarily dismantle its nuclear weapons	-1	-2	-8
4.	The continents which we live on are continually moving due to forces deep within the Earth	-1	-2	-8
5.	The price of petrol in South Africa is NOT influenced by the price of crude oil	-1	-2	-8
6.	Schizophrenia (PRONOUNCED SKIT-SO-FRENIA) is the same as Multiple Personality disorder	-1	-2	-8
7.	The father carries the genetic material that will determine if a baby is a boy or a girl	-1	-2	-8
8.	The earth's climate has NOT changed over millions of years	-1	-2	-8
9.	The main purpose of the Square Kilometre Array (SKA) radio telescope is to search for extra-terrestrial life	-1	-2	-8

Section B: Attitudes toward Science:

QX2. ASK ALL

SHOWCARD X2

OMO PER STATEMENT

ROTATE ORDER OF STATEMENTS

Please think about the following 4 statements and tell me to what degree you AGREE or DISAGREE with each of them.

Please use a scale where 1 is strongly agree, 2 is agree, 3 is neither agree nor disagree, 4 is disagree , and 5 is strongly disagree.

READ OUT STATEMENT AND SCALE. REPEAT SCALE AS NECESSARY

HAVE CAUTION TO USE THE CORRECT SHOWCARD AS THIS SCALE IS REVERSED

Attitudinal Statement	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	DON'T KNOW/ REFUSED (DNRO)
1. Science and technology are making our lives healthier, easier and more comfortable	-1	-2	-3	-4	-5	-8
2. It is not important for me to know about science in my daily life	-1	-2	-3	-4	-5	-8
3. Thanks to science and technology, there will be more opportunities for the future generation	-1	-2	-3	-4	-5	-8
4. The application of science and new technology makes our way of life change too fast	-1	-2	-3	-4	-5	-8

SECTION C: Interest in Science

QX3 ASK ALL

SHOWCARD X3

OMO PER AREA

ROTATE ORDER OF AREAS

Please indicate your general LEVEL OF INTEREST in developments along the following science and technology areas

READ OUT AREAS AND SCALE. REPEAT SCALE AS NECESSARY

	Interest Area	VERY INTERESTED	MODERATELY INTERESTED	NO INTEREST	DON'T KNOW (DNRO)
1.	Medical Science	-1	-2	-3	-8
2.	Climate Change	-1	-2	-3	-8
3.	Technology and the Internet	-1	-2	-3	-8
4.	Politics	-1	-2	-3	-8
5.	Economics	-1	-2	-3	-8
6.	Astronomy	-1	-2	-3	-8
7.	Energy	-1	-2	-3	-8

SECTION D: Level of Informedness

QX4 ASK ALL

SHOWCARD X4

OMO PER AREA

ROTATE ORDER OF AREAS

How WELL- INFORMED do you feel in your daily life related to the following issues

READ OUT AREAS AND SCALE. REPEAT SCALE AS NECESSARY

	Interest Area	VERY WELL INFORMED	MODERATELY WELL INFORMED	NOT WELL INFORMED	DON'T KNOW (DNRO)
1.	Medical Science	-1	-2	-3	-8
2.	Climate Change	-1	-2	-3	-8
3.	Technology and the Internet	-1	-2	-3	-8
4.	Politics	-1	-2	-3	-8
5.	Economics	-1	-2	-3	-8
6.	Astronomy	-1	-2	-3	-8
7.	Energy	-1	-2	-3	-8

SECTION E: Information Sources

QX 5 ASK ALL

SHOWCARD X5

OMO PER SOURCES

ROTATE ORDER OF SOURCES

Where do you most frequently encounter INFORMATION about science and technology matters

READ OUT SOURCE AND SCALE. REPEAT SCALE AS NECESSARY

PLEASE PROBE WITH RESPONDENT BEFORE SELECTING DON'T KNOW

	Information Source	MOST FREQUENTLY	OCCASIONALLY	LEAST FREQUENTLY	DON'T KNOW (DNRO)
1.	Satellite Pay Television such as DSTV or Star Sat	-1	-2	-3	-8
2.	Free-to-Air Television such as SABC or ETV	-1	-2	-3	-8
3.	Radio	-1	-2	-3	-8
4.	Newspapers	-1	-2	-3	-8
5.	News Websites	-1	-2	-3	-8
6.	Institutional Websites such as University or Research Labs	-1	-2	-3	-8
7.	Government Announcements	-1	-2	-3	-8
8.	Blogs	-1	-2	-3	-8
9.	Social media such as Facebook or Twitter	-1	-2	-3	-8
10.	Other people such as Family, Friends, or Colleagues	-1	-2	-3	-8
11.	Books / Magazines	-1	-2	-3	-8

SECTION F: Involvement in Engagement Activities

QX6 ASK ALL

SHOWCARD X6

OMO PER ACTIVITY

ROTATE ORDER OF ACTIVITIES

Have you have VISITED any of the following during the past 12 months

READ OUT ACTIVITIES AND REPEAT IF NECESSARY

	Science Engagement Activities	YES	NO	DON'T KNOW (DNRO)
1.	Public Library	-1	-2	-8
2.	Zoo or Aquarium	-1	-2	-8
3.	Museum (any)	-1	-2	-8
4.	Science Centre, Technology exhibition	-1	-2	-8
9.	Science Café, Festival or similar Public Event	-1	-2	-8

=======================================END=====================================

QUESTIONNAIRE SUMMARY INFORMATION

Question	Number of Items
SECTION A: Knowledge	**9**
SECTION B: Attitude	**4**
SECTION C: Interest	**7**
SECTION D: Informdness	**7**
SECTION E: Information sources	**11**
SECTION F: Engagement activities	**5**
TOTAL NUMBER OF ITEMS	**43**

Appendix 9

CODES BOOK - SPSS DATA FILE			
VARIABLE DESCRIPTION	SPSS VARIABLE NAME	CODE	LABEL
KNOWLEDGE ITEM 1: HIV AIDS	QH1_r1_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 2: LIGHTNING	QH1_r2_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 3: SA NUCLEAR WEAPONS	QH1_r3_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 4: PLATE TECTONICS	QH1_r4_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 5: PRICE OF PETROL IN SA	QH1_r5_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 6: SCHIZOPHRENIA	QH1_r6_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 7: HUMAN GENETICS	QH1_r7_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 8: CLIMATE CHANGE	QH1_r8_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
KNOWLEDGE ITEM 9: MAIN PURPOSE OF THE SKA	QH1_r9_answ	1	TRUE
		2	FALSE
		8	DON'T KNOW
ATTITUDE ITEM 1: PROMISE: SCIENCE MAKING LIFE SIMPLER, BETTER	QH2_r1_answ	1	STRONGLY AGREE
		2	AGREE
		3	NEITHER AGREE OR DISAGREE
		4	DISAGREE
		5	STRONGLY DISAGREE
		8	DON'T KNOW/ REFUSED
ATTITUDE ITEM 2: RESERVATION: NOT IMPORTANT TO KNOW ABOUT SCIENCE	QH2_r2_answ	1	STRONGLY AGREE
		2	AGREE
		3	NEITHER AGREE OR DISAGREE
		4	DISAGREE
		5	STRONGLY DISAGREE
		8	DON'T KNOW/ REFUSED

ATTITUDE ITEM 3: PROMISE: THANKS TO SCIENCE MORE OPPORTUNITIES	QH2_r3_answ	1	STRONGLY AGREE
		2	AGREE
		3	NEITHER AGREE OR DISAGREE
		4	DISAGREE
		5	STRONGLY DISAGREE
		8	DON'T KNOW/ REFUSED
ATTITUDE ITEM 4: RESERVATION: SCIENCE MAKES LIFE CHANGE TOO FAST	QH2_r4_answ	1	STRONGLY AGREE
		2	AGREE
		3	NEITHER AGREE OR DISAGREE
		4	DISAGREE
		5	STRONGLY DISAGREE
		8	DON'T KNOW/ REFUSED
INTEREST ITEM1: MEDICAL	QH3_r1_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INTEREST ITEM 2: CLIMATE CHANGE	QH3_r2_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INTEREST ITEM 3: TECHNOLOGY	QH3_r3_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INTEREST ITEM 4: POLITICS	QH3_r4_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INTEREST ITEM 5: ECONOMICS	QH3_r5_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INTEREST ITEM 6: ASTRONOMY	QH3_r6_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW

INTEREST ITEM 7: ENERGY	QH3_r7_answ	1	VERY INTERESTED
		2	MODERATELY INTERESTED
		3	NO INTEREST
		8	DON'T KNOW
INFORMEDNESS ITEM1: MEDICAL	QH4_r1_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 2: CLIMATE CHANGE	QH4_r2_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 3: TECHNOLOGY	QH4_r3_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 4: POLITICS	QH4_r4_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 5: ECONOMICS	QH4_r5_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 6: ASTRONOMY	QH4_r6_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMEDNESS ITEM 7: ENERGY	QH4_r7_answ	1	VERY WELL INFORMED
		2	MODERATELY WELL INFORMED
		3	NOT WELL INFORMED
		8	DON'T KNOW
INFORMATION SOURCES ITEM 1: SATELLITE TV	QH5_r1_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 2: SABC TV	QH5_r2_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW

INFORMATION SOURCES ITEM 3: RADIO	QH5_r3_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 4: NEWSPAPERS	QH5_r4_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 5: NEWS WEBSITES	QH5_r5_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 6: INSTITUTIONAL WEBSITES	QH5_r6_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 7: GOVERNMENT ANNOUNCEMENTS	QH5_r7_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 8: BLOGS	QH5_r8_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 9: SOCIAL MEDIA	QH5_r9_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 10: OTHER PEOPLE	QH5_r10_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
INFORMATION SOURCES ITEM 11: BOOKS / MAGAZINES	QH5_r11_answ	1	MOST FREQUENTLY
		2	OCCASIONALLY
		3	LEAST FREQUENTLY
		8	DON'T KNOW
SCIENCE ENGAGEMENT ITEM 1: LIBRARY	QH6_r1_answ	1	YES
		2	NO
		8	DON'T KNOW

SCIENCE ENGAGEMENT ITEM 2: ZOO	QH6_r2_answ	1	YES
		2	NO
		8	DON'T KNOW
SCIENCE ENGAGEMENT ITEM 3: MUSEUM	QH6_r3_answ	1	YES
		2	NO
		8	DON'T KNOW
SCIENCE ENGAGEMENT ITEM 4: SCIENCE CENTRE	QH6_r4_answ	1	YES
		2	NO
		8	DON'T KNOW
SCIENCE ENGAGEMENT ITEM 5: SCIENCE CAFÉ	QH6_r5_answ	1	YES
		2	NO
		8	DON'T KNOW
ATTITUDINAL ITEM RECODED 3 CATEGORIES	ATT_1_P1_RECODE	1	AGREE
		2	NEUTRAL
		3	DISAGREE
		8	D/K
ATTITUDINAL ITEM RECODED 3 CATEGORIES	ATT_2_R1_RECODE	1	AGREE
		2	NEUTRAL
		3	DISAGREE
		8	D/K
ATTITUDINAL ITEM RECODED 3 CATEGORIES	ATT_3_P2_RECODE	1	AGREE
		2	NEUTRAL
		3	DISAGREE
		8	D/K
ATTITUDINAL ITEM RECODED 3 CATEGORIES	ATT_4_R2_RECODE	1	AGREE
		2	NEUTRAL
		3	DISAGREE
		8	D/K
SELF-EMPLOYED (Y/N)	P6_SELF_EMPL	1	Yes
		2	No

RELIGION AFFILIATION	P29_RELIGION	1	Protestant (including Zionist, Baptist, Evangelical, Pentecostal, Methodist)
		2	Catholic
		3	Ancestral, tribal, animist, or other traditional African religion, such as Zulu or San beliefs
		4	Just a Christian
		5	Jehovah's Witness
		6	Mormon (Church of Jesus Christ of Latter-day Saints/LDS)
		7	Muslim
		8	Hindu
		9	Jewish
		10	Atheist
		11	Agnostic
		12	Nothing in particular
		13	Something else (SPECIFY)
		14	Don't know / Refused (DNRO)
AGE GROUP	P8_AGE_GROUP	1	01 - (15 – 17 years)
		2	02 - (18 – 19 years)
		3	03 - (20 – 24 years)
		4	04 - (25 – 29 years)
		5	05 - (30 – 34 years)
		6	06 - (35 – 39 years)
		7	07 - (40 – 44 years)
		8	08 - (45 – 49 years)
		9	09 - (50 – 54 years)
		10	10 - (55 – 59 years)
		11	11 - (60 – 64 years)
		12	12 - (65+ years)
		13	Refusal (DNRO)
MARITAL STATUS	P9_MARITAL	1	Single
		2	Married
		3	Living together
		4	Widowed
		5	Divorced
		6	Separated

EDUCATIONAL ATTAINMENT	P10_EDUCATION	1	No schooling
		2	Some primary school
		3	Primary school completed
		4	Some high school
		5	Matric / Grade 12
		6	Artisan's certificate obtained
		7	Technikon diploma/degree completed
		8	University degree completed
		9	Professional
		10	Technical
		11	Secretarial
		12	Other(Specify)
HOUSEHOLD INCOME	P11_2_HH_INCOME	1	01 - (R40 000 +)
		2	02 - (R30 000 – R39 999)
		3	03 - (R25 000 – R29 999)
		4	04 - (R20 000 – R24 999)
		5	05 - (R16 000 – R19 999)
		6	06 - (R14 000 – R15 999)
		7	07 - (R12 000 – R13 999)
		8	08 - (R11 000 – R11 999)
		9	09 - (R10 000 – R10 999)
		10	10 - (R9 000 – R9 999)
		11	11 - (R8 000 – R8 999)
		12	12 - (R7 000 – R7 999)
		13	13 - (R6 000 – R6999)
		14	14 - (R5 000 – R5 999)
		15	15 - (R4 000 – R4 999)
		16	16 - (R3000 – R3 999)
		17	17 - (R2500 – R2 999)
		18	18 - (R2000 – R2499)
		19	19 - (R1600 – R1 999)
		20	20 - (R1400 – R1599)
		21	21 - (R1200 – R1399)
		22	22 - (R1100 – R1199)
		23	23 - (R1000 – R1099)
		24	24 - (R900 – R999)
		25	25 - (R800 – R899)
		26	26 - (R700 – R799)
		27	27 - (R600 – R699)
		28	28 - (R500 – R599)
		29	29 - (R400 – R499)

		30	30 - (R300 – R399)
		31	31 - (R200 – R299)
		32	32 - (R1 – R199)
		33	98 - (No household income)
		34	96 - (No Answer)
PERSONAL INCOME	P11_3_PERSONAL_INCOME	1	01 - (R40 000 +)
		2	02 - (R30 000 – R39 999)
		3	03 - (R25 000 – R29 999)
		4	04 - (R20 000 – R24 999)
		5	05 - (R16 000 – R19 999)
		6	06 - (R14 000 – R15 999)
		7	07 - (R12 000 – R13 999)
		8	08 - (R11 000 – R11 999)
		9	09 - (R10 000 – R10 999)
		10	10 - (R9 000 – R9 999)
		11	11 - (R8 000 – R8 999)
		12	12 - (R7 000 – R7 999)
		13	13 - (R6 000 – R6999)
		14	14 - (R5 000 – R5 999)
		15	15 - (R4 000 – R4 999)
		16	16 - (R3000 – R3 999)
		17	17 - (R2500 – R2 999)
		18	18 - (R2000 – R2499)
		19	19 - (R1600 – R1 999)
		20	20 - (R1400 – R1599)
		21	21 - (R1200 – R1399)
		22	22 - (R1100 – R1199)
		23	23 - (R1000 – R1099)
		24	24 - (R900 – R999)
		25	25 - (R800 – R899)
		26	26 - (R700 – R799)
		27	27 - (R600 – R699)
		28	28 - (R500 – R599)
		29	29 - (R400 – R499)
		30	30 - (R300 – R399)
		31	31 - (R200 – R299)
		32	32 - (R1 – R199)
		33	98 - (No household income)
		34	96 - (No Answer)

COMMUNITY SIZE	CommSize	1	Metropolitan area
		2	City
		3	Large Town
		4	Small Town
		5	Large Village
		6	Small Village
		7	Settlement
		8	Rural
RACE GROUP	DEMOG_P19_POP_GROUP	1	White
		2	Black
		3	Indian / Asian
		4	Coloured
PROVINCE	DEMOG_Province	1	Western Cape
		2	Eastern Cape
		3	Northern Cape
		4	Free State
		5	KwaZulu Natal
		6	North West
		7	Gauteng
		8	Mpumalanga
		9	Limpopo
RURAL URBAN	DEMOG_RURAL_URBAN	1	URBAN
		2	RURAL
GENDER	DEMOG_P1_GENDER	1	Male
		2	Female
AGE - RECODED	DEMOG_New_AGE	1	<20 YEARS
		2	20-29 YEARS
		3	30-39 YEARS
		4	40-49 YEARS
		5	50-59 YEARS
		6	60+ YEARS
LANGUAGE SPOKEN	DEMOG_P2_LANGUAGE	1	Afrikaans
		2	English
		3	Ndebele
		4	North Sotho (Sepedi)
		5	South Sotho (Sesotho)
		6	Swazi
		7	Tsonga/Shangaan
		8	Tswana
		9	Venda
		10	Xhosa
		11	Zulu
		12	Other

EDUCATIONAL ATTAINMENT RECODED	DEMOG_NEW_EDUCATION	1	No schooling
		2	Primry School
		3	Some High School
		4	Matric completed
		5	Certificate / Diploma completed
		6	University Degree completed
		7	Other
EDUCATIONAL ATTAINMENT CATEGORIES	DEMOG_3_EDUCATION	1	PRE-MATRIC (1)
		2	MATRIC COMPLETED (2)
		3	POST-MATRIC (3)
EMPLOYMENT DETAIL	DEMOG_P5_EMPLOYMENT	1	Working full-time
		2	Working part-time
		3	Not Working - Housewife
		4	Not Working - Student
		5	Not Working - Retired
		6	Unemployed - looking for work
		7	Unemployed - not looking for work
EMPLOYMENT RECODED 3 CATEGORIES	DEMOG_EMPLOYMENT_RECODE	1	EMPLOYED (1)
		2	UNEMPLOYED (2)
		3	OTHER (NOT WORKING) (3)
HOUSEHOLD INCOME RECODED	DEMOG_HH_INCOME	1	01 - (R40 000 +)
		2	02 - (R30 000 – R39 999)
		3	03 - (R20 000 – R29 999)
		4	04 - (R10 000 – R19 999)
		5	05 - (R5 000 – R9 999)
		6	06 - (R0 001 – R4 999)
		7	07 - (No household income)
		8	08 - (No answer)
HOUSEHOLD INCOME 3 CATEGORIES	DEMOG_3_HH_INCOME	1	LOW INCOME (LESS THAN R10K) (1)
		2	MODERATE INCOME (BETWEEN R10K-R29K) (2)
		3	HIGH INCOME (R 30K+) (3)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_HIV_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_LIGHT_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)

KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_NUKE_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_PLATE_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_PETROL_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_PSYC_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_GENETICS_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_CLIMATE_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE ITEM RECODED CORRECT - INCORRECT	KNOW_SKA_RECODE	0	SCIENTIFICALLY INVALID (0)
		1	SCIENTIFICALLY VALID (1)
KNOWLEDGE_INDEX	KNOWLEDGE_INDEX	1	LOW (1)
		2	MODERATE (2)
		3	HIGH (3)
ATTITUDE_INDEX	ATTITUDE_INDEX	-1	NEGATIVE ATTITUDE (-1)
		0	AMBIVALENT ATTITUDE (0)
		1	POSITIVE ATTITUDE (+1)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_MED_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_CLIMATE_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_TECH_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_POL_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_ECON_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_ASTRO_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)

INTEREST ITEM RECODED 3 CATEGORIES	INTEREST_ENERGY_RECODE	0	NO INTEREST (0)
		1	MODERATE INTEREST (1)
		2	HIGH INTEREST (2)
INTEREST_INDEX	INTEREST_INDEX	1	LOW INTEREST (1)
		2	MODERATE INTEREST (2)
		3	HIGH INTEREST (3)
INFORMEDNESS ITEM RECODED	INFORM_MED_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_CLIMATE_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_TECH_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_POL_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_ECON_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_ASTRO_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)
INFORMEDNESS ITEM RECODED	INFORM_ENERGY_RECODE	0	D/K (0)
		1	NOT WELL INFORMED (1)
		2	MODERATE INFORMED (2)
		3	VERY WELL INFORMED (3)

INFORMEDNESS_INDEX	INFORMEDNESS_INDEX	1	LOW INFORMEDNESS (1)
		2	MODERATE INFORMEDNESS (2)
		3	HIGH INFORMEDNESS (3)
INFORMATION SOURCE RECODED	INFOSOURCE_PAYTV_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_FREETV_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_RADIO_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_NEWSPAPERS_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_NEWSwww_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_INSTITwww_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_GOV_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_BLOG_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_SOCwww_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFORMATION SOURCE RECODED	INFOSOURCE_PEOPLE_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)

INFORMATION SOURCE RECODED	INFOSOURCE_BOOKSMAGS_RECODE	0	D/K (0)
		1	LEAST FREQUENTLY (1)
		2	OCCASIONALLY (2)
		3	MOST FREQUENTLY (3)
INFOSOURCE_INDEX	INFOSOURCE_INDEX	1	LOW INFORMATION IMMERSION (1)
		2	MODERATE INFORMATION IMMERSION (2)
		3	HIGH INFORMATION IMMERSION (3)
SCIENCE ENGAGEMENT ITEM RECODED	ENG_LIB_RECODE	0	NO (0)
		1	YES (1)
SCIENCE ENGAGEMENT ITEM RECODED	ENG_ZOO_RECODE	0	NO (0)
		1	YES (1)
SCIENCE ENGAGEMENT ITEM RECODED	ENG_MUS_RECODE	0	NO (0)
		1	YES (1)
SCIENCE ENGAGEMENT ITEM RECODED	ENG_SCICEN_RECODE	0	NO (0)
		1	YES (1)
SCIENCE ENGAGEMENT ITEM RECODED	ENG_FEST_RECODE	0	NO (0)
		1	YES (1)
ENGAGEMENT_INDEX	ENGAGEMENT_INDEX	1	LOW ENGAGEMENT (1)
		2	MODERATE ENGAGEMENT (2)
		3	HIGH ENGAGEMENT (3)

Appendix 10

MULTINOMIAL LOGISTIC REGRESSION OUTPUTS:

SCIENTIFIC KNOWLEDGE INDEX:

Case Processing Summary

		N	Marginal Percentage
KNOWLEDGE_INDEX	LOW (1)	774	37.9%
	MODERATE (2)	530	26.0%
	HIGH (3)	737	36.1%
P19_POP_GROUP	White	227	11.1%
	Black	1558	76.3%
	Indian / Asian	76	3.7%
	Coloured	180	8.8%
DEMOG_RURAL_URBAN	URBAN	1392	68.2%
	RURAL	649	31.8%
DEMOG_P1_GENDER	Male	1038	50.9%
	Female	1003	49.1%
DEMOG_New_AGE	<20 YEARS	70	3.4%
	20-29 YEARS	605	29.6%
	30-39 YEARS	626	30.7%
	40-49 YEARS	377	18.5%
	50-59 YEARS	202	9.9%
	60+ YEARS	161	7.9%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	720	35.3%
	MATRIC COMPLETED (2)	987	48.4%
	POST-MATRIC (3)	334	16.4%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	1035	50.7%
	UNEMPLOYED (2)	696	34.1%
	OTHER (NOT WORKING) (3)	310	15.2%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	1431	70.1%
	MODERATE INCOME (BETWEEN R10K-R20K) (2)	466	22.8%
	HIGH INCOME (R 30K+) (3)	144	7.1%
Valid		2041	100.0%
Missing		1445	
Total		3486	
Subpopulation		530[a]	

a. The dependent variable has only one value observed in 303 (57.2%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	1813.310	.		
1	Removed	DEMOG_New_AGE	1822.302	8.992	10	.533
2	Removed	DEMOG_EMPLOYMENT_RECODE	1825.345	3.043	4	.551
3	Removed	DEMOG_RURAL_URBAN	1827.387	2.042	2	.360
4	Removed	DEMOG_P1_GENDER	1829.512	2.125	2	.346

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1931.190			
Final	1829.512	101.678	14	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1000.608	1044	.829
Deviance	1118.375	1044	.054

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1829.512[a]	.000	0	.
P19_POP_GROUP	1842.536	13.024	6	.043
DEMOG_3_EDUCATION	1849.143	19.631	4	.001
DEMOG_3_HH_INCOME	1860.721	31.209	4	.000

Parameter Estimates

KNOWLEDGE_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
MODERATE (2)	Intercept	.862	.339	6.458	1	.011			
	[P19_POP_GROUP=1]	-.348	.284	1.504	1	.220	.706	.405	1.231
	[P19_POP_GROUP=2]	-.347	.206	2.850	1	.091	.706	.472	1.058
	[P19_POP_GROUP=3]	-1.214	.401	9.176	1	.002	.297	.135	.651
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-.542	.205	6.958	1	.008	.582	.389	.870
	[DEMOG_3_EDUCATION=2.00]	.014	.185	.005	1	.942	1.014	.706	1.456
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_HH_INCOME=1.00]	-.854	.304	7.902	1	.005	.426	.235	.772
	[DEMOG_3_HH_INCOME=2.00]	-.409	.294	1.928	1	.165	.664	.373	1.183
	[DEMOG_3_HH_INCOME=3.00]	0[b]	.	.	0	.	.	.	.
HIGH (3)	Intercept	1.113	.313	12.682	1	.000			
	[P19_POP_GROUP=1]	.085	.261	.107	1	.743	1.089	.653	1.815
	[P19_POP_GROUP=2]	-.206	.195	1.115	1	.291	.814	.555	1.193
	[P19_POP_GROUP=3]	-.404	.320	1.593	1	.207	.668	.357	1.250
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-.124	.188	.436	1	.509	.883	.611	1.276
	[DEMOG_3_EDUCATION=2.00]	-.016	.172	.008	1	.928	.985	.702	1.380
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_HH_INCOME=1.00]	-1.166	.276	17.853	1	.000	.312	.181	.535
	[DEMOG_3_HH_INCOME=2.00]	-.481	.265	3.292	1	.070	.618	.368	1.039
	[DEMOG_3_HH_INCOME=3.00]	0[b]	.	.	0	.	.	.	.

a. The reference category is: LOW (1).

b. This parameter is set to zero because it is redundant.

ATTITUDE TO SCIENCE INDEX

Case Processing Summary			
		N	Marginal Percentage
ATTITUDE_INDEX	NEGATIVE ATTITUDE (-1)	443	20.7%
	AMBIVALENT ATTITUDE (0)	725	33.9%
	POSITIVE ATTITUDE (+1)	972	45.4%
DEMOG_RURAL_URBAN	URBAN	1461	68.3%
	RURAL	679	31.7%
DEMOG_P1_GENDER	Male	1082	50.6%
	Female	1058	49.4%
DEMOG_New_AGE	<20 YEARS	84	3.9%
	20-29 YEARS	653	30.5%
	30-39 YEARS	650	30.4%
	40-49 YEARS	384	17.9%
	50-59 YEARS	212	9.9%
	60+ YEARS	157	7.3%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	764	35.7%
	MATRIC COMPLETED (2)	1033	48.3%
	POST-MATRIC (3)	343	16.0%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	1092	51.0%
	UNEMPLOYED (2)	732	34.2%
	OTHER (NOT WORKING) (3)	316	14.8%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	1512	70.7%
	MODERATE INCOME (BETWEEN R10K-R20K) (2)	483	22.6%
	HIGH INCOME (R 30K+) (3)	145	6.8%
P19_POP_GROUP	White	229	10.7%
	Black	1640	76.6%
	Indian / Asian	79	3.7%
	Coloured	192	9.0%
Valid		2140	100.0%
Missing		1346	
Total		3486	
Subpopulation		538[a]	

a. The dependent variable has only one value observed in 312 (58.0%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	1876.856	.		
1	Removed	DEMOG_3_EDUCATION	1879.066	2.210	4	.697
2	Removed	DEMOG_EMPLOYMENT_RECODE	1882.338	3.272	4	.513
3	Removed	DEMOG_RURAL_URBAN	1884.504	2.166	2	.339
4	Removed	DEMOG_3_HH_INCOME	1889.852	5.347	4	.253
5	Removed	DEMOG_New_AGE	1902.563	12.711	10	.240
6	Removed	DEMOG_P1_GENDER	1906.285	3.722	2	.155

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1925.212			
Final	1906.285	18.927	6	.004

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1093.869	1068	.284
Deviance	1201.242	1068	.003

Likelihood Ratio Tests

Effect	Model Fitting Criteria: -2 Log Likelihood of Reduced Model	Likelihood Ratio Tests: Chi-Square	df	Sig.
Intercept	1906.285[a]	.000	0	.
P19_POP_GROUP	1925.212	18.927	6	.004

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

ATTITUDE_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B): Lower Bound	95% Confidence Interval for Exp(B): Upper Bound
AMBIVALENT ATTITUDE (0)	Intercept	.466	.226	4.272	1	.039			
	[P19_POP_GROUP=1]	-.328	.292	1.258	1	.262	.720	.406	1.278
	[P19_POP_GROUP=2]	.079	.236	.112	1	.738	1.082	.682	1.717
	[P19_POP_GROUP=3]	-.061	.394	.024	1	.878	.941	.435	2.036
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
POSITIVE ATTITUDE (+1)	Intercept	1.226	.201	37.159	1	.000			
	[P19_POP_GROUP=1]	-.487	.260	3.501	1	.061	.614	.369	1.023
	[P19_POP_GROUP=2]	-.491	.212	5.382	1	.020	.612	.404	.927
	[P19_POP_GROUP=3]	-.335	.359	.871	1	.351	.716	.354	1.445
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.

a. The reference category is: NEGATIVE ATTITUDE (-1).

b. This parameter is set to zero because it is redundant.

INTEREST IN SCIENCE INDEX

Case Processing Summary			
		N	Marginal Percentage
INTEREST_INDEX	LOW INTEREST (1)	577	33.0%
	MODERATE INTEREST (2)	608	34.8%
	HIGH INTEREST (3)	563	32.2%
DEMOG_RURAL_URBAN	URBAN	1222	69.9%
	RURAL	526	30.1%
DEMOG_P1_GENDER	Male	901	51.5%
	Female	847	48.5%
DEMOG_New_AGE	<20 YEARS	72	4.1%
	20-29 YEARS	545	31.2%
	30-39 YEARS	527	30.1%
	40-49 YEARS	319	18.2%
	50-59 YEARS	168	9.6%
	60+ YEARS	117	6.7%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	590	33.8%
	MATRIC COMPLETED (2)	853	48.8%
	POST-MATRIC (3)	305	17.4%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	910	52.1%
	UNEMPLOYED (2)	590	33.8%
	OTHER (NOT WORKING) (3)	248	14.2%
P19_POP_GROUP	White	197	11.3%
	Black	1360	77.8%
	Indian / Asian	46	2.6%
	Coloured	145	8.3%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	1219	69.7%
	MODERATE INCOME (BETWEEN R10K-R20K) (2)	403	23.1%
	HIGH INCOME (R 30K+) (3)	126	7.2%
Valid		1748	100.0%
Missing		1738	
Total		3486	
Subpopulation		473[a]	

a. The dependent variable has only one value observed in 280 (59.2%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	1646.714	.		
1	Removed	DEMOG_P1_GENDER	1648.394	1.680	2	.432
2	Removed	DEMOG_EMPLOYMENT_RECODE	1653.606	5.212	4	.266
3	Removed	DEMOG_3_HH_INCOME	1659.981	6.375	4	.173
4	Removed	DEMOG_New_AGE	1675.958	15.977	10	.100

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1768.065			
Final	1675.958	92.107	12	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	965.698	932	.216
Deviance	1067.480	932	.001

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1675.958[a]	.000	0	.
DEMOG_RURAL_URBAN	1687.602	11.643	2	.003
DEMOG_3_EDUCATION	1710.237	34.279	4	.000
P19_POP_GROUP	1702.917	26.959	6	.000

Parameter Estimates

INTEREST_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	95% Confidence Interval for Exp(B) Upper Bound
MODERATE INTEREST (2)	Intercept	-.049	.263	.034	1	.854			
	[DEMOG_RURAL_URBAN=1.00]	-.051	.128	.159	1	.690	.950	.740	1.221
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-.396	.200	3.939	1	.047	.673	.455	.995
	[DEMOG_3_EDUCATION=2.00]	-.079	.189	.175	1	.676	.924	.638	1.338
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[P19_POP_GROUP=1]	.355	.276	1.660	1	.198	1.426	.831	2.447
	[P19_POP_GROUP=2]	.341	.194	3.077	1	.079	1.406	.961	2.058
	[P19_POP_GROUP=3]	.991	.429	5.348	1	.021	2.695	1.163	6.243
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
HIGH INTEREST (3)	Intercept	-.768	.309	6.184	1	.013			
	[DEMOG_RURAL_URBAN=1.00]	.386	.140	7.625	1	.006	1.471	1.118	1.934
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-1.056	.197	28.730	1	.000	.348	.236	.512
	[DEMOG_3_EDUCATION=2.00]	-.521	.181	8.314	1	.004	.594	.417	.846
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[P19_POP_GROUP=1]	1.189	.315	14.210	1	.000	3.282	1.769	6.089
	[P19_POP_GROUP=2]	1.145	.256	19.994	1	.000	3.143	1.903	5.193
	[P19_POP_GROUP=3]	1.320	.482	7.492	1	.006	3.743	1.455	9.630
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.

a. The reference category is: LOW INTEREST (1).

b. This parameter is set to zero because it is redundant.

INFORMEDNESS ABOUT SCIENCE INDEX

Case Processing Summary

		N	Marginal Percentage
INFORMEDNESS_INDEX	LOW INFORMEDNESS (1)	678	31.2%
	MODERATE INFORMEDNESS (2)	763	35.1%
	HIGH INFORMEDNESS (3)	732	33.7%
P19_POP_GROUP	White	227	10.4%
	Black	1671	76.9%
	Indian / Asian	79	3.6%
	Coloured	196	9.0%
DEMOG_RURAL_URBAN	URBAN	1473	67.8%
	RURAL	700	32.2%
DEMOG_P1_GENDER	Male	1102	50.7%
	Female	1071	49.3%
DEMOG_New_AGE	<20 YEARS	84	3.9%
	20-29 YEARS	665	30.6%
	30-39 YEARS	646	29.7%
	40-49 YEARS	392	18.0%
	50-59 YEARS	217	10.0%
	60+ YEARS	169	7.8%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	786	36.2%
	MATRIC COMPLETED (2)	1045	48.1%
	POST-MATRIC (3)	342	15.7%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	1092	50.3%
	UNEMPLOYED (2)	747	34.4%
	OTHER (NOT WORKING) (3)	334	15.4%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	1544	71.1%
	MODERATE INCOME (BETWEEN R10K-R20K) (2)	485	22.3%
	HIGH INCOME (R 30K+) (3)	144	6.6%
Valid		2173	100.0%
Missing		1313	
Total		3486	
Subpopulation		543[a]	

a. The dependent variable has only one value observed in 318 (58.6%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	1907.463	.		
1	Removed	DEMOG_P1_GENDER	1909.346	1.883	2	.390

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2157.452			
Final	1909.346	248.106	30	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1096.869	1054	.175
Deviance	1202.849	1054	.001

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1909.346[a]	.000	0	.
P19_POP_GROUP	1952.898	43.552	6	.000
DEMOG_RURAL_URBAN	1935.669	26.323	2	.000
DEMOG_New_AGE	1927.588	18.242	10	.051
DEMOG_3_EDUCATION	1958.322	48.976	4	.000
DEMOG_EMPLOYMENT_RECODE	1920.439	11.093	4	.026
DEMOG_3_HH_INCOME	1918.291	8.945	4	.063

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

INFORMEDNESS_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
MODERATE INFORMEDNESS (2)	Intercept	.604	.423	2.039	1	.153			
	[P19_POP_GROUP=1]	-.342	.280	1.493	1	.222	.710	.410	1.230
	[P19_POP_GROUP=2]	-.269	.183	2.164	1	.141	.764	.534	1.094
	[P19_POP_GROUP=3]	-1.305	.330	15.597	1	.000	.271	.142	.518
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_RURAL_URBAN=1.00]	.477	.117	16.497	1	.000	1.611	1.280	2.028
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_New_AGE=1.00]	.453	.347	1.705	1	.192	1.572	.797	3.101
	[DEMOG_New_AGE=2.00]	.151	.239	.400	1	.527	1.163	.728	1.860
	[DEMOG_New_AGE=3.00]	-.004	.243	.000	1	.988	.996	.619	1.603
	[DEMOG_New_AGE=4.00]	.375	.252	2.211	1	.137	1.455	.888	2.384
	[DEMOG_New_AGE=5.00]	.059	.267	.050	1	.824	1.061	.629	1.791
	[DEMOG_New_AGE=6.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-.726	.224	10.511	1	.001	.484	.312	.750
	[DEMOG_3_EDUCATION=2.00]	-.450	.207	4.724	1	.030	.637	.425	.957
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_EMPLOYMENT_RECODE=1.00]	.494	.184	7.208	1	.007	1.640	1.143	2.352
	[DEMOG_EMPLOYMENT_RECODE=2.00]	.456	.184	6.103	1	.013	1.577	1.099	2.264
	[DEMOG_EMPLOYMENT_RECODE=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_HH_INCOME=1.00]	-.560	.326	2.949	1	.086	.571	.302	1.082
	[DEMOG_3_HH_INCOME=2.00]	-.428	.318	1.808	1	.179	.652	.349	1.216
	[DEMOG_3_HH_INCOME=3.00]	0[b]	.	.	0	.	.	.	.
HIGH INFORMEDNESS (3)	Intercept	.184	.444	.172	1	.678			
	[P19_POP_GROUP=1]	.728	.294	6.133	1	.013	2.070	1.164	3.683
	[P19_POP_GROUP=2]	.474	.219	4.687	1	.030	1.607	1.046	2.470
	[P19_POP_GROUP=3]	-.890	.368	5.849	1	.016	.411	.200	.845

	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_RURAL_URBAN=1.00]	.592	.125	22.398	1	.000	1.807	1.414	2.309
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_New_AGE=1.00]	1.131	.354	10.198	1	.001	3.099	1.548	6.204
	[DEMOG_New_AGE=2.00]	.350	.262	1.785	1	.182	1.420	.849	2.374
	[DEMOG_New_AGE=3.00]	.161	.266	.367	1	.545	1.175	.698	1.977
	[DEMOG_New_AGE=4.00]	.311	.278	1.250	1	.264	1.364	.791	2.353
	[DEMOG_New_AGE=5.00]	.237	.291	.663	1	.415	1.268	.716	2.245
	[DEMOG_New_AGE=6.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-1.444	.221	42.632	1	.000	.236	.153	.364
	[DEMOG_3_EDUCATION=2.00]	-.818	.199	16.934	1	.000	.441	.299	.652
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_EMPLOYMENT_RECODE=1.00]	.550	.193	8.155	1	.004	1.734	1.188	2.530
	[DEMOG_EMPLOYMENT_RECODE=2.00]	.529	.196	7.300	1	.007	1.697	1.156	2.492
	[DEMOG_EMPLOYMENT_RECODE=3.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_HH_INCOME=1.00]	-.839	.318	6.976	1	.008	.432	.232	.805
	[DEMOG_3_HH_INCOME=2.00]	-.525	.308	2.910	1	.088	.592	.324	1.081
	[DEMOG_3_HH_INCOME=3.00]	0[b]	.	.	0	.	.	.	.

a. The reference category is: LOW INFORMEDNESS (1).

b. This parameter is set to zero because it is redundant.

INFORMATION SOURCES

Case Processing Summary			
		N	Marginal Percentage
INFOSOURCE_INDEX	LOW INFORMATION IMMERSION (1)	677	32.2%
	MODERATE INFORMATION IMMERSION (2)	664	31.6%
	HIGH INFORMATION IMMERSION (3)	760	36.2%
P19_POP_GROUP	White	229	10.9%
	Black	1615	76.9%
	Indian / Asian	78	3.7%
	Coloured	179	8.5%
DEMOG_RURAL_URBAN	URBAN	1439	68.5%
	RURAL	662	31.5%
DEMOG_P1_GENDER	Male	1067	50.8%
	Female	1034	49.2%
DEMOG_New_AGE	<20 YEARS	78	3.7%
	20-29 YEARS	633	30.1%
	30-39 YEARS	635	30.2%
	40-49 YEARS	381	18.1%
	50-59 YEARS	209	9.9%
	60+ YEARS	165	7.9%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	748	35.6%
	MATRIC COMPLETED (2)	1016	48.4%
	POST-MATRIC (3)	337	16.0%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	1069	50.9%
	UNEMPLOYED (2)	712	33.9%
	OTHER (NOT WORKING) (3)	320	15.2%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	1478	70.3%
	MODERATE INCOME (BETWEEN R10K-R20K) (2)	480	22.8%
	HIGH INCOME (R 30K+) (3)	143	6.8%
Valid		2101	100.0%
Missing		1385	
Total		3486	
Subpopulation		534[a]	

a. The dependent variable has only one value observed in 316 (59.2%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	1837.225	.		
1	Removed	DEMOG_EMPLOYMENT_RECODE	1842.839	5.614	4	.230
2	Removed	DEMOG_3_HH_INCOME	1848.831	5.993	4	.200
3	Removed	DEMOG_P1_GENDER	1853.206	4.374	2	.112

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2090.208			
Final	1853.206	237.003	22	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1058.372	1044	.372
Deviance	1172.243	1044	.003

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	1853.206[a]	.000	0	.
P19_POP_GROUP	1873.267	20.061	6	.003
DEMOG_RURAL_URBAN	1863.895	10.689	2	.005
DEMOG_New_AGE	1880.020	26.814	10	.003
DEMOG_3_EDUCATION	1958.253	105.047	4	.000

Parameter Estimates

INFOSOURCE_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
MODERATE INFORMATION IMMERSION (2)	Intercept	.487	.334	2.123	1	.145			
	[P19_POP_GROUP=1]	-.151	.294	.264	1	.607	.860	.483	1.531
	[P19_POP_GROUP=2]	-.386	.206	3.529	1	.060	.680	.454	1.017
	[P19_POP_GROUP=3]	-.353	.364	.940	1	.332	.702	.344	1.434
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_RURAL_URBAN=1.00]	.209	.119	3.059	1	.080	1.232	.975	1.557
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_New_AGE=1.00]	.257	.343	.562	1	.454	1.293	.660	2.535
	[DEMOG_New_AGE=2.00]	.115	.218	.278	1	.598	1.122	.732	1.719
	[DEMOG_New_AGE=3.00]	.266	.214	1.537	1	.215	1.304	.857	1.985
	[DEMOG_New_AGE=4.00]	.232	.227	1.044	1	.307	1.262	.808	1.970
	[DEMOG_New_AGE=5.00]	.647	.250	6.711	1	.010	1.910	1.171	3.116
	[DEMOG_New_AGE=6.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-.629	.208	9.100	1	.003	.533	.354	.802
	[DEMOG_3_EDUCATION=2.00]	-.565	.202	7.816	1	.005	.568	.383	.845
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.
HIGH INFORMATION IMMERSION (3)	Intercept	.536	.351	2.333	1	.127			
	[P19_POP_GROUP=1]	.177	.282	.391	1	.532	1.193	.686	2.074
	[P19_POP_GROUP=2]	-.544	.207	6.894	1	.009	.580	.387	.871
	[P19_POP_GROUP=3]	-.180	.352	.262	1	.609	.835	.419	1.665
	[P19_POP_GROUP=4]	0[b]	.	.	0	.	.	.	.
	[DEMOG_RURAL_URBAN=1.00]	.405	.124	10.610	1	.001	1.499	1.175	1.912
	[DEMOG_RURAL_URBAN=2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_New_AGE=1.00]	1.005	.365	7.564	1	.006	2.731	1.335	5.588
	[DEMOG_New_AGE=2.00]	.876	.254	11.908	1	.001	2.401	1.460	3.948
	[DEMOG_New_AGE=3.00]	.716	.252	8.049	1	.005	2.046	1.248	3.355
	[DEMOG_New_AGE=4.00]	.898	.262	11.782	1	.001	2.456	1.470	4.102
	[DEMOG_New_AGE=5.00]	.801	.293	7.494	1	.006	2.228	1.256	3.955

	[DEMOG_New_AGE=6.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION=1.00]	-1.779	.201	78.554	1	.000	.169	.114	.250
	[DEMOG_3_EDUCATION=2.00]	-.910	.185	24.282	1	.000	.403	.280	.578
	[DEMOG_3_EDUCATION=3.00]	0[b]	.	.	0	.	.	.	.

a. The reference category is: LOW INFORMATION IMMERSION (1).

b. This parameter is set to zero because it is redundant.

SCIENCE ENGAGEMENT INDEX

Case Processing Summary

		N	Marginal Percentage
ENGAGEMENT_INDEX	LOW ENGAGEMENT (1)	290	47.9%
	MODERATE ENGAGEMENT (2)	148	24.4%
	HIGH ENGAGEMENT (3)	168	27.7%
P19_POP_GROUP	White	107	17.7%
	Black	422	69.6%
	Indian / Asian	16	2.6%
	Coloured	61	10.1%
DEMOG_RURAL_URBAN	URBAN	469	77.4%
	RURAL	137	22.6%
DEMOG_P1_GENDER	Male	311	51.3%
	Female	295	48.7%
DEMOG_New_AGE	<20 YEARS	45	7.4%
	20-29 YEARS	194	32.0%
	30-39 YEARS	182	30.0%
	40-49 YEARS	101	16.7%
	50-59 YEARS	54	8.9%
	60+ YEARS	30	5.0%
DEMOG_3_EDUCATION	PRE-MATRIC (1)	108	17.8%
	MATRIC COMPLETED (2)	334	55.1%
	POST-MATRIC (3)	164	27.1%
DEMOG_EMPLOYMENT_RECODE	EMPLOYED (1)	365	60.2%
	UNEMPLOYED (2)	139	22.9%
	OTHER (NOT WORKING) (3)	102	16.8%
DEMOG_3_HH_INCOME	LOW INCOME (LESS THAN R10K) (1)	345	56.9%

	MODERATE INCOME (BETWEEN R10K-R20K) (2)	192	31.7%
	HIGH INCOME (R 30K+) (3)	69	11.4%
Valid		606	100.0%
Missing		2880	
Total		3486	
Subpopulation		288[a]	

a. The dependent variable has only one value observed in 205 (71.2%) subpopulations.

Step Summary

Model	Action	Effect(s)	Model Fitting Criteria	Effect Selection Tests		
			-2 Log Likelihood	Chi-Square[b]	df	Sig.
0	Entered	<all>[a]	789.872	.		
1	Removed	P19_POP_GROUP	793.193	3.321	6	.768
2	Removed	DEMOG_EMPLOYMENT_RECODE	796.687	3.494	4	.479
3	Removed	DEMOG_New_AGE	810.492	13.805	10	.182
4	Removed	DEMOG_3_HH_INCOME	817.468	6.976	4	.137
5	Removed	DEMOG_P1_GENDER	821.920	4.452	2	.108

Stepwise Method: Backward Elimination

a. This model contains all effects specified or implied in the MODEL subcommand.

b. The chi-square for removal is based on the likelihood ratio test.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	861.923			
Final	821.920	40.003	6	.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	585.576	568	.296
Deviance	631.131	568	.034

Likelihood Ratio Tests

Effect	Model Fitting Criteria: -2 Log Likelihood of Reduced Model	Likelihood Ratio Tests: Chi-Square	df	Sig.
Intercept	821.920[a]	.000	0	.
DEMOG_RURAL_URBAN	837.710	15.789	2	.000
DEMOG_3_EDUCATION	840.008	18.088	4	.001

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

Parameter Estimates

ENGAGEMENT_INDEX[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B): Lower Bound	Upper Bound
MODERATE ENGAGEMENT (2)	Intercept	-.800	.289	7.649	1	.006			
	[DEMOG_RURAL_URBAN =1.00]	.221	.235	.888	1	.346	1.248	.788	1.977
	[DEMOG_RURAL_URBAN =2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION= 1.00]	-.011	.311	.001	1	.971	.989	.538	1.819
	[DEMOG_3_EDUCATION= 2.00]	-.058	.253	.053	1	.819	.944	.575	1.548
	[DEMOG_3_EDUCATION= 3.00]	0[b]	.	.	0	.	.	.	.
HIGH ENGAGEMENT (3)	Intercept	-.870	.311	7.826	1	.005			
	[DEMOG_RURAL_URBAN =1.00]	1.061	.286	13.798	1	.000	2.891	1.651	5.061
	[DEMOG_RURAL_URBAN =2.00]	0[b]	.	.	0	.	.	.	.
	[DEMOG_3_EDUCATION= 1.00]	-1.211	.337	12.892	1	.000	.298	.154	.577
	[DEMOG_3_EDUCATION= 2.00]	-.663	.223	8.802	1	.003	.516	.333	.799
	[DEMOG_3_EDUCATION= 3.00]	0[b]	.	.	0	.	.	.	.

a. The reference category is: LOW ENGAGEMENT (1).

Appendix 11

NOTIFICATION OF ACCEPTANCE INTO PhD PROGRAM

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

25 November 2011

Mr S Parker (16970381-2011)
PO Box 37
GATESVILLE
7766

Dear Mr Parker

APPROVEMENT OF TITLE OF DISSERTATION

The Senate decided on 25 November 2011 to approve the title of your dissertation and to allow you to register for the continuation of the PhD (Science and Technology) programme.

Title of dissertation: "Development of indicators for the South African public's relationship with Science."

You have to register for the continuation of the doctoral programme not later than the end of March 2012. You can register at the Administration Building Block A, room 3003/3007 or per fax or per post.

If you prefer to register by fax, our bank details are as follow:

Credit:	University of Stellenbosch
Bank:	ABSA - Stellenbosch
Branch number:	33441045
Account number:	0410204789
Reference:	Please use your student number as reference number
Fax:	Please fax proof of payment, together with your postal registration form, to Ms MC Loxton at: 086 564 0031.

Yours faithfully

MC Loxton

Ms MC Loxton
for **REGISTRAR**

/pk

Navrae/Enquiries: Ms MC Loxton
Tel: (021) 808 9111
Verw./Ref.: 60/8/1

Rig asseblief alle korrespondensie aan die Registrateur/Please address all correspondence to the Registrar
Universiteitskantoor/University Offices
Privaatsak/Private Bag X1 • 7602 Matieland • Suid-Afrika/South Africa • Faks/Fax: +27 (0)21 808 3822

NOTIFICATION OF ETHICS APPROVAL

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
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Approval Notice

Stipulated documents/requirements

03-Dec-2015
Parker, Saahier S

Proposal #: SU-HSD-001128

Title: Development of Indicators for the Measurement of South African Publics' Understanding of Science

Dear Mr Saahier Parker,

Your **Stipulated documents/requirements** received on , was reviewed and has been accepted.

Please note the following information about your approved research proposal:

Proposal Approval Period: 07-Sep-2015 - 06-Sep-2016

General comments:

Please take note of the general Investigator Responsibilities attached to this letter.

If the research deviates significantly from the undertaking that was made in the original application for research ethics clearance to the REC and/or alters the risk/benefit profile of the study, the researcher must undertake to notify the REC of these changes.

Please remember to use your **proposal number** (SU-HSD-001128) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2015 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)